JOURNAL

OF

THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

FEBRUARY, 1865.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Leveling and Surveying by means of a Visual Angle and Rod.

Treated by S. W. ROBINSON, C. E.

THIS method of leveling and surveying, I think has not, as yet, come into so general use as its merits demand. Where extreme accuracy is not required, it is a rapid means of performing many field operations, which, as now usually done, require both the leveling and transit instruments.

To form a visual angle with which to make readings upon the rod with suitable exactness, a telescope, provided with a reticule of spider's threads is required. For leveling purposes we must have a vertical graduated limb upon the axis of the telescope; and for plotting the work, readings from a horizontal limb. The theodolite then is the instrument best adapted to the purpose.

The visual angle may be variable,—formed between two spider-threads in the focus of the instrument, one or both of which is moveable by a micrometer head,—or they may be stationary forming a constant angle. The latter is probably preferable, in consequence of the liability of the micrometer to get out of adjustment; and of a greater amount of computation required to reduce the observations.

The constant visual angle should usually be within the limits of 25 to 35 minutes of arc.

To determine a distance, this angle being known, let the instrument

be centered over one of the two points between which the distance is to be found, and the rod provided with two targets, over the other; and both targets adjusted to appear to the observer to be exactly upon the two horizontal threads. When the distance between the two targets is measured, we have the base of an isoceles triangle in which all the angles become known.

But a much more convenient arrangement than the rod and targets, is a flat surface of three or four inches width and the required length, painted in such a manner that the distance can be read to a foot by the observer himself. By the French this is called a *stadia*. One of the best forms for painting the stadia is represented in Fig. 1, A B corresponding to a distance of 100 feet, A *a*, *a b*, *b c*, &c. to distances of 10 feet. Closer readings come from estimation. In this, after a little practice there is never any trouble in getting the nearest foot. Narrower spaces become indistinct at too short distances; but a stadia like Fig. 1, is easily read to the nearest foot with an ordinary Würdemann theodolite at a distance of 1500 feet. This distance with a vertical angle of 25 or 30 degrees closely read, will determine the height of several hundred feet to the fraction of a foot.

FIG. 1.

A sufficient number of courses run over an irregular surface of ground, an azimuth carried* and readings noted:—these points and their heights plotted upon paper will give at once the topography, and this too, probably by the *most rapid method*, except perhaps the plane table in the open field. Preliminary lines can be expeditiously run; and leveling done for profiles, &c., while all the reading and measuring is under the direct control of the engineer himself.

The error of the stadia measurement has been found to be about one foot in 800 or 1000; one foot in 1000, being that usually allowed in chaining. To my knowledge courses have been run from one to six miles, over heights of 150 to 200 feet, in which the final error in height ranged from 0 to 1·5 feet with no more than ordinary care.

The stadia was used for getting the topography of some densely wooded timber land in the summer of 1863. The courses were so run as to connect points of triangulation from one to four miles apart. The distances from point to point along the courses, ranged from 100 to 500 ft. The latitudes and departures were subsequently computed with the object of finding the error of stadia measurement. The results obtained were about 1 foot in 800, 1000, and 1100 feet.

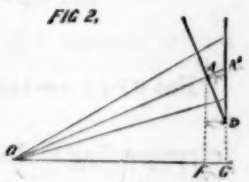
In the month of October last, a base of 1347·3 feet was measured with the stadia giving 1346 ft. Also a base of 1798·9 ft., by two persons; giving independently, 1800 ft. and 1798 ft.

* That is,—keeping the 0° and 180° points of the horizontal limb constantly in a line parallel to that of their first position; which is done by keeping the vernier and limb, or upper movement clamped after the fore-sight is taken till after the instrument is carried forward and a back-sight is taken upon this same stake, and the lower movement clamped. Then the upper movement is to be unclamped and the telescope turned for taking the next fore-sight.

I give the following formulæ as results of my investigation of the problem of surveying with the visual angle and stadia.

For a solution which shall be general and strictly rigorous, it must be observed that all the unrefracted rays which pass an object-glass cross at its optical centre, and that the vertex of the visual angle is at this point formed by lines produced through the glass from the spider-threads of the diaphragm. Also it must be observed that these threads approach, or recede from the object-glass by adjusting the focus, which changes the magnitude of the visual angle. The position in which the stadia should be held while taking an observation upon it should be first considered. If it could always stand at the same height as the telescope forming the visual angle, there would be no question as to a vertical position. But in practice almost every observation is taken while the central visual ray forms an angle with the plane of the horizon. The stadia may be inclined to a perpendicular to this ray, or it might still be held vertical. Sights may be attached for adjusting it to the former, or a plumb for adjusting to the latter position. In the former case the distance read would always be O A, Fig. 2, and O A cos A O F = O F. But the stadia stands upon a stake at D: hence the required horizontal distance would be O G = O F + A D sin (D A F = A O F); and the height G A′ = O A sin A O F + A D $\frac{\sin^2 AOF}{\cos AOF}$. A D being usually five feet or more, its correction would be too great to be neglected. Probably a more convenient formula for computing is obtained by always observing the stadia while vertical. As will be shown below, the reading will become O A′ very approximately by multiplying by cos A′ O F. This into the sine or cosine A′ O F, gives A′ G or O G; formulas which are convenient for logarithms. All the following investigations will be made for the stadia in a vertical position.

FIG 2.



Let us suppose the instrument centred over the point A, Fig. 3, and the stadia stationed at the point B.

Let the required distance A H = x,

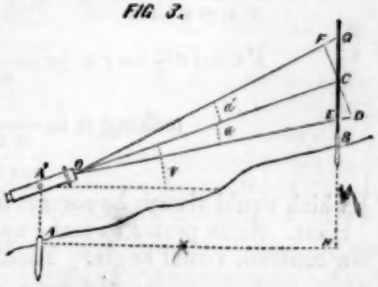
and height H B = y.

Let v = the angle of O C with the horizon, and

r = reading of the stadia.

Let the telescope be provided with a reticule of one vertical and three horizontal threads forming two partial visual angles a a'.

FIG 3.



Then F C G = E C D = v; and G E = reading stadia = r. C F G = 90° + a'; C G F = 180° − v − (90° + a') = 90° − (v + a'); C D E = 90° − a; C E D = 90°

$-(v-a)$. We have C F : C G :: sin 90° $-(v+a')$: sin 90° $+ a'$ :: cos $(v+a')$: cos a', whence

$$\text{C G} = \frac{\text{C F} \cos a'}{\cos (v+a')}. \quad \text{Similarly} \quad \text{C E} = \frac{\text{C D} \cos a}{\cos (v-a)}, \quad . \quad (1)$$

and we will have

$$\text{E G} = \text{C G} + \text{C E} = \frac{\text{C F} \cos a'}{\cos (v+a')} + \frac{\text{C D} \cos a}{\cos (v-a)}.$$

Put C D : C F :: m : n :: tang a' : tang a' $\therefore$ C D = C F $\frac{m}{n}$. (2)

Then

$$\text{E G} = \text{C F}\left(\frac{\cos a'}{\cos (v+a')} + \frac{m \cos a}{n \cos (v-a)}\right) = \text{C D}\left(\frac{n \cos a'}{m \cos (v+a')} + \frac{\cos a}{\cos (v-a)}\right)$$

$$\therefore \text{C F} = \frac{\text{E G}}{\left(\frac{\cos a'}{\cos (v+a')} + \frac{m \cos a}{n \cos (v-a)}\right)},$$

$$\text{and C D} = \frac{\text{E G}}{\left(\frac{n \cos a'}{m \cos (v+a')} + \frac{\cos a}{\cos (v-a)}\right)}.$$

But C F + C D = reading of the stadia corrected to F D,

corresponding to dist. o C $= r \left\{ \frac{1}{\frac{\cos a'}{\cos (v+a')} + \frac{m \cos a}{n \cos (v-a)}} + \right.$

$$\left. \frac{1}{\frac{n \cos a'}{m \cos (v+a')(v-a)} + \frac{\cos 2\,a}{\cos (v-a)}} \right\} = \frac{r\,(m+n)}{\frac{n \cos a'}{\cos (v+a')} + \frac{m \cos a}{\cos (v-a)}}. \quad . \quad (4)$$

which is the reading of stadia E G reduced to D F, without regard to the relative values of a a'.

This corresponds to the distance C O.

Let the quantity O A', intervening between the object-glass and Y s, $= c$ then

$$\text{A}'\text{C} = \text{O C} + c = r\,\text{M} + c = \frac{x}{\cos v} = \frac{y}{\sin v}, \quad . \quad . \quad (5)$$

$$\text{making M} = \frac{m+n}{\frac{n \cos a'}{\cos (v+a')} + \frac{m \cos a}{\cos (v-a)}},$$

which would always be correct for A' C if the angle $(a+a')$ could be constant. Some prefer to make no adjustment of the focus which secures a constant visual angle. Then

$$x = \text{A}'\text{C} \cos v \text{ and } y = \text{A}'\text{C} \sin v. \quad . \quad (6)$$

But I design to make the solution general for a perfect adjustment of the focus.

Let us consider then a third correction due to adjustment of focus. Call this correction z. Then, instead of (5) we have

$$A'C = \frac{x}{\cos v} = \frac{y}{\sin v} = rM + c + z = s + c. \quad . \quad (7)$$

We have yet to determine z.

We have for the general equation of the varying focus of a convex lens

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{s}, \text{ or } u = \frac{sf}{s-f}, \quad . \quad . \quad (8)$$

in which if f=principal focal length, u=focal length for an object at a distance s.

For our case let s always be regarded as equal o C, Fig. 3. Measure a distance which on the horizontal plane A H Fig. 3, $= x'$, and for this let $z = o$ when $v = o$, then

$$(A'C) = x' = r' + c = s' + c, \quad . \quad . \quad (9)$$

And for any other point where the stadia may be set we will have the expression equation (7); and

$$s' = r', \qquad s = rM + z, \quad . \quad . \quad (11)$$

r' being that particular reading for the stadia at a distance x'. We will have two values of u Eq. (8)

$$u = \frac{sf}{s-f} \text{ and } u' = \frac{s'f}{s'-f} \quad . \quad . \quad (12)$$

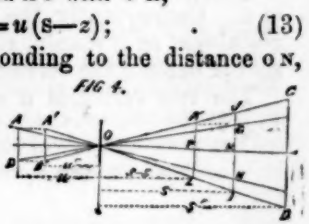
in which if s is less than s', u' is less than u.

In Fig. 4, if o be the object-glass; A'D' and A D the positions of the spider lines for objects at distances s' and s, we will have, as will be plain by making A' o coincide with o B, and A o with o H,

$$u : u' :: s : s - z, \text{ or } u's = u(s - z); \quad . \quad (13)$$

since s would be the reading I J, corresponding to the distance o N, and $s - z$ the reading N G or K L, or distance o P if there were no correction for change of focus. Substituting in (13), u and u' from (12), s' and s from (11), and reducing we get

FIG 4.



$$z = f\left(1 - \frac{rM}{r'}\right), \quad . \quad . \quad (14)$$

This in (7) and reduced gives

$$A'C = rM\left(1 - \frac{f}{r'}\right) + c + f \quad . \quad . \quad (15)$$

If we make $v = o$ and $r = x' - c = r'$, we have $A'C = x'$. Make $r = o$; then $A'C = f + c$. But we see r only equals the distance read when $r = r'\left(1 + \frac{c}{f}\right)$ $\frac{3}{2}r'$ nearly. But in making the stadia originally it is convenient to have the reading equal the true distance x'. And as

it is proposed to make the stadia a scale of equal parts, the readings from different scales will be proportional to those scales. We may then put $r'+c=\text{R}'=$ reading. Then we will have

$$r : \text{R}'-c :: \text{R} : \text{R}', \text{ or } r=\text{R}\left(1-\frac{c}{\text{R}'}\right), \quad . \qquad (16)$$

which combined with (7), (9), (11) and (12) give

$$(\text{A}'\text{C})=x'=\text{R}'=\text{S}'+c, \ \text{A}'\text{C}=\frac{x}{\cos v}=\text{R}\left(1-\frac{c}{\text{R}'}\right)\text{M}+c+z=\text{S}+c,$$

$$z=f\left(1-\frac{\text{R M}}{\text{R}'}\right)=f\left(1-\frac{\text{R M}}{x'}\right), \quad . \qquad (17)$$

and $$\text{A}'\text{C}=\frac{x}{\cos v}=\frac{y}{\sin v}=\text{RM}\left(1-\frac{c+f}{x'}\right)+c+f. \qquad (18)$$

It sometimes happens that we wish to use a stadia whose divisions are too great or small, when it becomes necessary to multiply the reading by a co-efficient which will correct it. Let e represent this co-efficient. We will then have, for $\text{M}=$unity, $\text{R}e=x'=\text{R}'e$, $\therefore e=\frac{x'}{\text{R}'}$, and (18) becomes

$$\text{A}'\text{C}=\frac{x}{\cos v}=\frac{y}{\sin v}=e\,\text{RM}\left(1-\frac{c+f}{x'}\right)+c+f. \qquad (20)$$

This is the formula required. If $e=$ unity, and $v=o$ or $\text{M}=$ unity, and $\text{R}=o$, $\text{A}'\text{C}=f+c$; that is, when the stadia is at a distance f from the object-glass, or at its principal focal distance, the eye-piece and diaphragm are an infinite distance away, and the visual angle $(a+a')=o$. Consequently the reading must be zero. Make $\text{R}=\text{R}'$, then $x=\text{R}'=x'$ as it should, since at this point we desire that the reading should become the correct distance.

The two variables a and a' are yet to be considered. We have, Fig. 3.

$$\tan a_1=\frac{\text{C D}}{\text{O C}}=\text{C E}\frac{\cos(v-a_1)}{x'\cos a_1}\cos v,$$

$$\tan a'_1=\frac{\text{C F}}{\text{O C}}=\text{C G}\frac{\cos(v+a'_1)}{x'\cos a'_1}\cos v,$$

a_1 and a'_1 being the angles when $\text{R}=\text{R}'$; and CE, CG, absolute quantities measured upon the stadia. We also have, Fig. 4.

tang a : tang a_1 :: u' : u, or tang $a=$ tang $a_1\,\frac{u'}{u}$, and tang $a'=$tang $a'_1\,\frac{u'}{u}$, which become known by substituting for u, S and z.

These formulas are hardly ever necessary except perhaps for making the stadia originally. The following may be of use when our base is not on a level plane. Let $\text{D}=$amount intercepted by the visual an-

gle at a horizontal distance x', and with a vertical angle v; and $d=$ the amount which would be intercepted if $v=o$. Then

$$\frac{d}{\cos v} = \text{D M} + z = \text{D M} - f\frac{\text{D M}}{d} + f,$$

since d corresponds to x' and D to R in (17),

$$\therefore\ d^2 - d\,(\text{D M} + f)\cos v = f\,\text{D M}\cos v$$

If $v=o$, M = unity and $d=$ D.

The stadia may be divided into such a variable scale as to make its own corrections for adjustment of focus. To make such a stadia, let the amount intercepted by the visual angle at a distance $x'=1000$ ft., be measured; then the amount intercepted at 100 feet equals that at 1000 feet diminished by $z=f\left(1-\frac{100}{1000}\right)$ $\frac{9}{10}f$; or $\frac{9}{10}f\tan(a+a')$ in absolute measure.

In practice there are approximate formulas which are sufficiently accurate for reducing field notes.

Usually $a=a'$ nearly, and by neglecting them altogether we introduce an error proportionate to a direct function of v, of only about $\frac{1}{1000}$ for $v=26°$. Hence dropping a and a' from (18) we get

$$x = \text{R}\cos^2 v\left(1-\frac{c+f}{x'}\right)+(c+f)\cos v, \qquad (21)$$

$$y = \tfrac{1}{2}\text{R}\sin 2v\left(1-\frac{c+f}{x'}\right)+(c+f)\sin v, \qquad (22)$$

that is,—to reduce observations upon a stadia which is uniformly divided, and for the focus in adjustment, *we will have the horizontal distance equal the reading, multiplied into a constant and the square of the cosine of the vertical angle, plus a constant into the cosine of the vertical angle;—and the height equal the reading into a constant and the sine of twice the vertical angle, plus a constant into the sine of the vertical angle.*

Values of $(c+f)$ (sine or cosine) may be arranged in a table. Also $1-\cos^2 v\left(1-\frac{c+f}{x'}\right)$ which will give a difference to multiply by R and subtract, which will usually be small. The quantity $\frac{\text{R}}{2}\sin 2v\left(1-\frac{c+f}{x'}\right)$ which is required more accurately may be calculated from a table, but generally there would be no advantage over the use of logarithms.

Formulas still less approximate than (21) and (22), but more convenient in practice are obtained by making $(c+f)=o$. We will then have

$$x_1 = \text{R} \cos^2 v, \quad \text{and} \quad y_1 = \text{R}\tfrac{1}{2} \sin 2v. \qquad (24)$$

Subtracting these from (21) and (22)

$$x - x_1 = (c+f)\left(1 - \frac{\text{R}}{x'} \cos v\right) \cos v,$$

$$y - y_1 = (c+f)\left(\sin v - \frac{\text{R}}{x'} \cdot \tfrac{1}{2} \sin 2v\right).$$

If $x'=$ about 1000, as it should; and R never exceeding about 1500, the maximum values of the above differences is when $\text{R} = o$. If $v=o$ and $\text{R} = o$, $x - x_1 = (c+f) =$ max. = about 18 or 20 inches. If $v = 10°$ which it hardly ever exceeds, and $\text{R} = o$, $y - y_1 = (c+f)$ 0·17 = max. = about 3 or 4 inches.

Hence, the error of x, in (24) *can never exceed* 18 *or* 20 *inches, nor that of y* 3 *or* 4 *inches for a telescope one foot in length kept in adjustment of focus.*

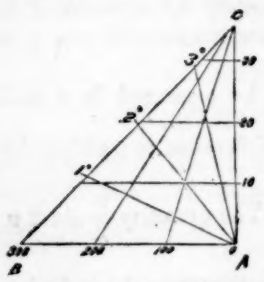
Equations (24) become more exact by adding the quantity $\frac{x' - \text{R}}{x'}$ $(c+f)$. Hence

$$x = \text{R} \cos^2 v + \frac{x' - \text{R}}{x'}(c+f) \cos v \text{ nearly}, \qquad (25)$$

$$y = \text{R}\tfrac{1}{2} \sin 2v + \frac{x' - \text{R}}{x'}(c+f) \sin v \text{ nearly}, \qquad (26)$$

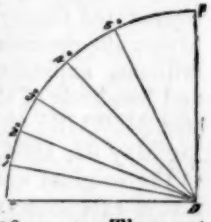
These formulas or even (24) are sufficiently exact for most cases of topography.

The quantity y, (eq. 24) may be determined graphically. There are several methods, two of which are given below.



Let AB, be the base of a triangle equally divided to represent feet = R by lines drawn from C. Draw lines parallel to AB intersecting AC at equidistant points to represent heights $= y$; and let lines drawn from A to B C represent angles v. These latter points of intersection must be calculated. To obtain y from this triangle, find the distance R on A B, then follow that line toward C till we meet the line of our vertical angle v; then following one of the lines parallel to AB to its intersection with A C, we will find the number corresponding to y. It may be convenient to be provided with a number of these triangles made for great and small values of R and v.

A quadrant which I understand was invented in Europe, answers a good purpose.



Let lines radiating from D represent the vertical angle v, and so divide E F that if R be taken from a scale and laid off from D on the line representing v, then the vertical distance above ED to that point measured on the same scale should $= 10y$.

This quantity divided by ten divides the error of the operation by ten. Five quadrants are required to reach $v = 45°$. The first, for the quantity $\frac{1}{2} \sin 2v$, ends with $v = 5°\ 46'\ 6{\cdot}5''$, where $10\,y = $ R. The next quadrant gives quantities from zero up, which must be added to R and the whole divided by ten. For the third quadrant we must add 2 R &c. The second quadrant ends with 11° 47′ 20·7″. The third with 18° 26′ 5·8″. The fourth with 26° 33′ 54·2″. The fifth with 45° 0′ 0″.

For leveling purposes the index error of the vertical limb should be known, and the stadia should have some point to be easily distinguished, to be used for adjusting the vertical angle before taking its reading. One of the spots which mark the 100 feet as A or B Fig. 1, and about the height of the instrument, may be painted red. The plumb-bob of the instrument may be suspended by a chain, or something more stable than a chord, to be used to determine the height of the instrument. The chain may be provided with hooks corresponding to 10, 20, &c. feet on the stadia, which will tell what point above or below the red target upon the stadia to sight at. The height of instrument may also be found by a tape-line.

For taking back sights a "barber's-pole" is useful, painted with alternate black, or red and white divisions, corresponding in length to those of the stadia, from which to count the 100 feet, to secure the observer against mistakes.

If it is required to make the stadia perpendicular to the line of sight when read; we will have M, Eq's (5) and (20),=unity. We must then add the quantity depending upon A D, Fig. 2. Thus Eq's (24) become

$$x_1 = \text{R} \cos v + \text{A D} \sin v, \qquad y_1 = \text{R} \sin v + \text{A D} \frac{\sin^2 v}{\cos v}.$$

The quantities depending upon A D may be tabulated.

For the Journal of the Franklin Institute.

Papers on Hydraulic Engineering. By SAMUEL MCELROY, C.E.,

Continued from Vol. xlvii, page 11.

No. 5.—*Fire Service and Hydrants.*

The value of water supply, for fire service, is one of the strongest arguments usually presented for its introduction; an argument which gains force by careful attention to the disproportion between annual fire loss and cost of water administration. It is not uncommon in city

experience, that a single conflagration should much exceed in pecuniary loss, the entire cost of an ample supply, or should be so much aggravated through defective supply, as to exceed largely the cost of proper improvements; and while annual fire statistics are counted by millions, expenditures for the preventive, are counted by thousands and hundreds of thousands. The loss by fire in Philadelphia, in 1862, was $450,176; the loss reported in New York for the six months ending May 31, 1864, was $2,512,696, or about one-ninth the entire cost of the original works, while the cost of annual administration, exclusive of extension, was $108,760; the loss at Cleveland in 1861-2, was $227,000, the original cost of water supply being $550,000 and the annual administration, without extensions, $9,117; and cases of special conflagrations might be cited, which, as at Troy, or Albany, sweep a large part of a whole city out of existence, and are registered in the columns of millions. While a part of this article was being written, the telegraph flashed an account, across the wires, of $750,000 loss, in one night, on the American Hotel block at Buffalo, exceeding by $220,000 the cost of her water-works, on which property, the annual city tax alone, far exceeded the whole annual expense of water administration.

In the Paper on Distribution, Vol. xliv, pages 145 and 217, a brief allusion was made to hydrants, under the head of "appurtenances;" this subject, in connexion with that of fire-service, is so directly associated with the theory of adequate water supply, for ordinary and extraordinary delivery, as to require a systematic discussion, which follows as a proper sequel to that of distribution, and includes its more important features.

With this object, we propose to examine, in their order, and in brief, the general *office* and *methods of distribution systems*, the *progress of fire-engines*, the *conditions of fire service*, and its *improvement*, the *defects of distribution* and proposed corrections, the *progress of fire-hydrants* with their *contingencies* and *defects*, and the *improvements* suggested.

Office of Distribution.—Water is required for drinking, cooking, washing, bathing, street-cleaning, and for extinguishing fires, as prominent private and public applications for individual comfort and safety and general health; and it fulfils these several offices, through various mechanical appendages to the distribution system, which are known as faucets, turn-cocks, stand-pipes, hydrant-pumps, drinking-hydrants, fountains, horse-troughs, street-washers, fire-plugs and various other names, characteristic of their special uses, and which are very much diversified in form and action. Of this entire class we have to do at present with but two or three members, in which certain adaptations of form to use, and its contingencies, are of special consequence.

Methods of Distribution.—The operation of all distributing appurtenances is directly affected by the character of the supply to which they are attached, whether of the Low Service, Intermittent or Constant High Service, there being essential differences of method in different localities, in this respect.

The Low Service is defined by the use of the supply, under very

moderate head, or without pressure, after its reception at the place of use. This was the general nature of ancient supplies, though modified by special exceptions, and prevailed, although the principle of conveyance under excessive pressure was fully understood and practised on the aqueduct lines, and in cases of city distribution, so far as the feeding and service mains were concerned.

As we have noticed in the paper on Reservoirs, (Vol. xliii, page 291,) the reservoir conduits of Rome, as one example, were arranged to supply the public fountains first, the public baths next, and lastly the several dwellings.

A greater part of the citizens resorted to the public fountains for domestic supply, as is now customary in many countries of the Old World, while in the courts of the private palaces and other luxurious dwellings, fountains were kept in play and cisterns were constructed for special reserve supply. The various public and private fountains and cisterns were therefore used as receptacles, from which the ordinary supply for domestic uses was taken by hand.

These fountains are in such admirable preservation at the present day, as to attract the attention of travelers, furnishing a luxurious addition to the attractions of the ancient city.

Of the manner in which Pompeii was supplied, the following quotation, by Mr. Earnshaw of the Cincinnati water-works, is sufficiently concise:

"The letting out of the public water to private persons was a source of revenue, the supervision of which was entrusted to an officer of high rank, and many precautions were taken to prevent fraud in this matter. The aqueducts were each charged with a certain number of supply pipes, and no new pipe could be inserted without a special application to the Emperor. Permission being obtained, the applicant was assigned a calix, as it was called, of the assigned dimensions. This was a brass measure fixed in the castellum or reservoir, the diameter of which regulated the quantity of water which could pass through it, and for which the applicant was charged. Beyond the calix, the pipe was private property, but more effectually to prevent fraud, it was enacted that for a distance of fifty feet, the calix and the pipe should be of the same diameter. The right to a supply of water was strictly personal, not attached to houses, and the supply was cut off at every change of ownership, and the right previously granted, was sold by the superintendents to the highest bidder. Those inhabitants whose means of interest were insufficient to obtain a private supply pipe were obliged to carry their supply from the public fountains." —*Library of Entertaining Knowledge.*

Not only did this general system prevail in the supplies of the Old World, but it is common to many cities of the present time, in which the service of the water carriers are almost entirely relied upon for domestic uses; in the present century, cities like Paris have depended on such processes of daily house supply, while in London, the Low Service is a very recent characteristic of its distribution, and so of many other European towns.

The ancient system, however, was constant in its operation, and available at all times when required. It was reserved for modern times to inaugurate a change, which added to the disadvantages of the Low Service, the ill-advised and miserly features of the *Intermittent System.*

Under this method, as at London, the several companies each sub-

divided its general district of supply, into minor districts, of which but one was supplied at a time, and at intervals varying from one to three days, the times of such supply being a limited number of hours in length. The consumers were therefore obliged to find special storage for their supply, in tanks, cisterns, tubs, pails and the like, to carry them through the intervals, and added to the objectionable features of the Thames and New River water itself, the grave objections which pertain to such kinds of storage. The effects on fire supply are referred to by Mr. Matthews, in his *Hydraulia*, edition of 1835, page 71, as follows:

"Formerly the Water Companies of the metropolis did not profess to supply higher than the ground floor of any house, and therefore it was not their practice to keep the pipes constantly full of water, both day and night, as at present is the case. In fact, prior to the adoption of the effective system now pursued, they found it necessary to be very economical in its distribution; and during the nights the valve at the upper end of the mains was usually shut, so that when a fire happened, however alarming or extensive it might be, it was necessary to send a messenger to the person stationed at the New River head, or some of the other sources, to apprise them of the accident, before a supply of water could be obtained. Watchmen were likewise employed for the particular purpose of being constantly on the look-out for fires, and as soon as discovered, to convey with the utmost speed, information to the respective water-works, of the precise place where they had occurred. But the delays usually and unavoidably attendant upon this practice, were productive of serious evils, and the destructive element would often make dreadful havoc, before any water could be procured to diminish or destroy its power."

The improvement in maintaining a charge of water in the street main here referred to, dates back to a period earlier than 1818, for some of the London Companies, as will be noticed in an extract from a letter of J. Walker, C.E., to Frederick Graff, C.E., engineer of the Fairmount Water Works, dated London, April 6, 1818:—

"After the district is supplied, it is desirable that all the cocks on the mains be opened; and that the principal mains be always kept full of water in case of fire, an inconvenience arising from this is that if *ball cocks* in the houses which are supplied directly from the mains are not attached, or are not kept in repair, a great waste of water is the consequence; as the water is laid on to the houses throughout the whole of the day. To remedy this it is not unusual to run a pipe of supply parallel to the main, with communications and stop-cocks at proper distances between the main and it; and to let all the private pipes communicate with the smaller pipe only. The water is thus laid on to the houses in the streets through which the main runs, for a limited time only, in the same manner as in the cross streets; and the main is not allowed to be broke into for private pipes."

The *Constant High Service* by which the distribution mains and pipes are always kept under the reservoir head, is not without a number of examples in Europe, as at Glasgow, Hamburg, and some other cities, but with us, is so universal, and was so early introduced, as to merit the title of the American System; its European use being, in many cases, the result of our example on recent works.

The differences in manner of use and of pressure contingent on these differences of system, affect all classes of distributing appurtenances.

Of fire-hydrants in particular it may be said that their office has been of a much less important character under the Low and Intermittent Systems than under that of continual and severe pressure, which requires a more careful use and a much more careful construction.

Progress of Fire Engines.—In connexion with the effects of method in distribution, we have also to consider those changes in the manner of extinguishing fires, which have served to give increased importance to the character of our fire-hydrants, and which have also been affected by processes of supply.

The records of skill among the ancients, in hydraulic machines, are full of interest, and the drawings and accounts of water clocks, pumps, engines and other ingenious applications in hydrodynamics, show an advanced knowledge of the science. From these records it is known that much attention was paid to precautions against fires and their extinguishment by the organization of special companies and the use of forcing engines. One of these, as used in Egypt, in the second century before Christ, contains an air chamber in the discharge tube, and is in many respects similar to the modern type, though without suction apparatus, or supply independent of buckets or equivalent hand labor from the fountains and cisterns of the time, and it is evident that while powerful pumping engines were in use among the ancients, such use was more particularly confined to military operations, and the ordinary fire engines, down to a very modern date, were of small size and limited power, the chief reliance being placed on manual labor, with buckets, ladders and hooks.

The modern fire engine of any capacity which entitles it to consideration, dates about the year 1729, according to Ewbank, (*Hydraulics*, page 334,) as the invention of Richard Newsham, an English engineer. This engine is of the "goose-neck" pattern, with a pair of single acting pumps worked by chains attached to a double sector, with a long vertical air chamber, and a suction tube.

Small engines, fitted with leathern hose for delivery, and afterward for suction, were introduced in Amsterdam in 1672.

In the city of New York, about 1648, ladders, hooks, and buckets, were imported from Holland, for fire purposes; and the Newsham fire engines were ordered for city use in 1730, being the first of the class on record. In many cities of the United States, within the present century, the fire apparatus has been equally primitive with that of New York before 1731, as is the case at present, in many villages and small settlements.

The most important addition to our fire- departments, however careful and costly the arrangement of their hand-engines, has been recently made by the successful introduction and adoption of steam fire engines. The arguments in their favor are evident, in city experience, on account of their superior power and endurance, and the remedies they offer, at no distant day, to the growing evils of the volunteer system, have made it certain that all the details of engine supply must be remodeled to meet the conditions of this novel addition to the class under discussion.

The use of stationary steam pumps for fires and safeguards, is no novelty in many of our cities. In New York, with the gradual loss of head in the city below 14th street, hotels and factories have been

compelled to adopt this precaution, on an extensive scale; the pumping department of the St. Nicholas Hotel, on Broadway, with its connected branch lines of delivery throughout the house, is arranged with large outlay in cost, and with special completeness in all its details; such expenditures throughout the lower city evince a full conviction of the necessities of the time, and the imperfections of the water supply proper. Of such a provision applied to public uses, the Report on Water Supply of Providence, R. I., thus speaks:

"In this city, street pipes are connected with the steam pumps of various factories. By the report of the Fire Department, submitted in May of this year, (1856,) it appears that up to that time 4780 feet of iron pipes had been laid, and 25 hydrants established in connexion with them. Now this system of using steam engine power for forcing water through pipes laid down under the streets, to be used at fires, once commenced, has got to be extended over the whole city."

The Report then very properly argues the superior economy of a reservoir supply.

Although Mr. Ericsson obtained the prize of the Mechanics' Institute of New York, in 1840, for the best plan of steam fire engine, these engines have not taken a place in practical operation until more than 20 years later. Having various mechanical difficulties to perfect, in which direction much is yet to be accomplished, and having bitter and powerful prejudices to overcome, they have been slow in gaining a position from which they cannot now be dislodged. Their correctness of principle is established, and when their construction in detail is more carefully based on the laws which govern all pumping engines, their perfection of performance will be duly attained. Without pausing to discuss this matter, it is enough to understand that this element of fire service must be fully developed by adequate details of supply.

It follows, then, from this sketch of different systems of service and of progress in fire-engines, that fire-hydrants, as we have them, are creations of the American system and of the nineteenth century, since it has been reserved for the more recent conditions of service, to call into action appurtenances specially adapted to their requirements.

Conditions of Fire Service.—To those who have given this matter attention, it is evident that fires may have various producing causes, and in their extinction may involve various degrees of effort. Fires arising from causes which are readily perceived, differ from those which may be for some time secretly at work; and fires which increase in fury by degree, differ from those produced by violent and sustained agencies; those occurring in buildings of careful construction and easy of access, differ from cases in inflammable structures, or those excessively high, or on elevated ground. There are fires, therefore, which with any moderate exertion are easily subdued, and there are those which will tax all the energies of the best organized department and the most perfect service, in their swift and destructive progress. As there may be a time when a small jet of water will prove an adequate extinguisher, so there may be a time when water will but add fuel to the flames.

The following abstracts of causes of fire, embody statistics, which are sufficient for our present argument under this head:

Average of 17 years experience in London, in causes of fire.

Causes.	Cases.	Causes.	Cases.
Unavoidable accident,	27	Defective hearths,	1
Ignited apparel on the person,	4	Hot cinders put away,	3
Accidents with candles,	169	Lamps,	5
Palpable carelessness,	18	Slaking lime,	4
Children, playing with fire,	14	Drying linen,	30
Drunkenness,	5	Lucifer matches,	11
Fire heat in manufacturing processes,	26	Ovens,	7
Fire sparks,	21	Reading and smoking in bed,	1½
Fire works,	4	Loose shavings,	20
Fires on hearth,	7	Spontaneous combustion,	13
Defective or foul flues,	75	Defective or overheated stoves,	37
Incautious fumigation,	3	Tobacco smoking,	14
Gas,	46	Suspicious,	7
Gunpowder,	1⅓	Wilful,	12

The results are thus given for the same average:

	Cases.
Slightly damaged,	470
Seriously damaged,	212
Total loss,	26
Insured,	478
Uninsured,	230

For the six months ending May 31, 1864, in New York, of 195 fires and alarms reported, the causes of 125 are thus analyzed:

Causes.	Cases.	Causes.	Cases.
Kerosene oil,	3	Grates,	4
Benzine,	2	Hot air furnace and registers,	4
Ashes,	2	Dripping fat,	2
Matches in hands of children,	17	Stove and stove pipes,	15
Candles and lamps,	14	Window curtains,	7
Chimney flues,	22	Forges,	2
Drying rooms,	2	Tin roofers' fire-pots,	2
Fire places,	3	Gas stove,	1
Sparks on roofs,	2	Intoxication,	3
Furnaces,	3	Steam boiler explosions,	2
Gas and gas-lights,	12		

Deaths by fire.

In burning buildings,	3
Explosions of kerosene oil,	3
Other causes,	55

The inference from these chapters of investigated and analyzed cases, where the causes have been determined officially, makes it plain that the greater part of the fires might easily have been prevented by means which should be readily within reach; and while the second London chapter conveys a singular lesson on the great disproportion of insured premises, it more fully on this account, argues the need of prompt remedies for suspicious cases; it is to be observed, also, that the total and serious losses are but fifty per cent. of the entire class.

Aside from general statistics, many prominent instances will occur

at once to memory, which illustrate either the want of a remedy immediately at hand, or the fatal effect of inadequate appliances.

Cases abound, similar to that of the Jersey City Ferry buildings, where a supply comparatively prompt, has yet proved entirely inadequate in force, from the hydrants, to reach the roofs, which were less than half the reservoir level.

The prominent lesson of our fire experience is a continuous comment on the necessity of prompt remedies; this is particularly true of wilful fires and those of violent causes, and it involves a question of advantage as to time of application and as to adequate power. The contingencies often place life in danger, no less than property, and delays frequently result, in the case of partial losses, in more damage from water than from fire.

In the great majority of cases with us, and in Europe, the entire reliance is placed on the fire department, whether under the control of the Insurance Companies as in London, or the city government, as commonly arranged. Those cases are exceptional which provide for fire service by superior reservoir heads and careful details of special service, and practically dispense with fire engines.

Nor does experience justify the abandonment of a fire service adapted to the management of serious conflagrations, whatever may be the facility for hydrant supply, since such cases demand a concentration of effort and an expenditure of power, which cannot be otherwise had, and fire service generally requires something more than water-jets. But while we do not argue the possibility of dispensing with this provision for cases of more than ordinary character, it is clear that within a certain limit, provision is important for remedies of a more simple character, and more immediately available.

With us, in large cities, where watchmen are constantly on duty in elevated places, and police telegraphs are carefully maintained, it will still consume from 3 to 5 minutes to give a public alarm, designating by bell strokes, the special district where a fire has occurred; with an average speed of ten miles an hour for the engines, and an average run of a mile and upwards, the time of engine travel will be from 8 to 12 minutes; and the placement of engines on the ground and commencement of supply will take from 5 to 10 minutes, making from 16 to 27 minutes lapse before a stream is at work.

Testimony on this point at London, where great care is observed at the engine houses to keep a force on the alert, shows that from 30 to 40 minutes generally elapse before the engines are fully at work. With us the time varies considerably, but it must be admitted that the shortest period above estimated is frequently exceeded.

In most cases this period will suffice for considerable headway; in experience this is manifestly so, fires being well under way, as a rule, before the first engine stream is opened. This very necessity of delay, plainly permits an amount of damage, which could not otherwise occur. It is given as the result of long continued observation, by those whose practice qualifies them to judge correctly, that not less than two-thirds of our fires become serious from the absence of prompt remedies.

With the fire department at work, as usual, not only on the burning premises, but those adjacent, or on the burning portion of the premises, it follows that large quantities of water are often used in actually destroying property, and such destruction forms no small part of insurance restitution or personal loss.

It is also clear from the painful chapters of fire casualty, that much of this might be spared with a more prompt relief; every moment of delay in such cases being fatal in its effects.

Delays may not only be inherent in dependence on the fire department, but this service may be embarrassed by deficiencies in kind or amount of power, or in the distribution service, or by contingencies of the time. Cases are not uncommon in which conflagrations have reached a point where fire engines give way to gunpowder explosions, or where severe frost has made hydrants, hose, and machines useless appurtenances; but it is the province of true wisdom to anticipate all such casualties, so far as human foresight or human experience may avail.

From these conditions we see that the management of fires, involves proper attention to two distinct processes; one of which must meet those cases, which may be speedily corrected, and the other must guard those more serious cases, which require all the appliances of an organized and powerful department. These processes should be distinct in provision though capable of united action.

Improvement of Fire Service.—The previous investigation makes it plain that very great benefits would be secured by the addition to our ordinary fire service of a method fully capable of more prompt application than is now possible. This method involves the use of a hose and hydrant service, before the arrival of the fire engines, and must therefore be an addition to the ordinary fire department.

The introduction of water supply in our larger cities, has been followed by the organization and equipment of hose companies, with the idea of such an independent method of service, in part, and as an improvement on the old system of hose carts or reels, attached to the fire engines. But it is a matter of fact, in practice, and of necessity from their company organization, that hose carts of the improved school, are no less tardy in coming on the ground and into action, than the engines, and by consequence, the chief feature of improvement must be differently arranged to secure the leading element of promptness for those numerous cases which specially require it.

The following tables of statistics from the Brooklyn Reports, embody interesting information as to the average amount of hydrant and hose service, required in a period of three years.

Brooklyn Fire service in 1861, Piped District.

MONTH.	No.of fires.	Estimated damage.	No. of Hydrants used.	No. of Lengths of Hose used.	Whole time in use.	Average time per Hydrant.
		Dollars.			h. m.	h. m. s.
January,	6	15,725	26	. .	10 30	24 6
February,	11	7,455	44	548	16 14	21 22
March,	16	6,110	62	515	32 52	31 51
April,	9	1,725	26	143	2 20	20
May,	8	7,300	29	187	7 0	14 14
June,	3	1,400	17	142	1 0	3 9
July,	14	6,125	45	363	6 36	8 36
August,	12	8,075	44	332	55 25	1 15 34
September,	7	34,255	31	449	28 52	55 52
October,	4	4,600	12	144	8 40	43 20
November,	4	1,400	18	159	13 0	43 20
December,	2	2,500	12	57	12 55	1 4 35
	96	96,670	366	3039	195 24	
Per fire,			3·81	31·5		

Brooklyn Fire service in 1862, Piped District.

MONTH.	No.of fires.	Estimated damage.	No. of Hydrants used.	No. of Lengths of Hose used.	Whole time in use.	Average time per Hydrant.
		Dollars.			h. m.	h. m. s.
January,	10	18,525	44	290	72 55	1 39 25
February,	9	1,810	36	242	17 35	26
March,	8	7,300	40	315	33 10	49 45
April,	5	7,700	25	253	7 5	1 25
May,	14	347,970	68	847	201 39	2 59 50
June,	8	14,250	43	264	65 45	1 28 12
July,	3	10,000	14	84	24 10	1 43
August,	3	1,000	7	73	1 33	13 17
September,	1	2,500	5	45	1 25	17
October,	0	6,650	38	290	6 30	10 10
November,	7	4,300	23	228	4 25	11 21
December,	5	1,500	16	113	1 30	5 10
	83	423,505	359	3044	437 42	
Per fire,			4·20	36·3		

Brooklyn Fire service in 1863, Piped District.

MONTH.	No. of fires.	Estimated damage.	No. of Hydrants used.		Whole time in use.	Average time per Hydrant.
		Dollars.			h. m.	h. m. s.
January,	5	3,500	18		13 25	44 13
February,	10	11,000	30		26 0	52
March,	14	18,500	50		8 50	10 30
April,	9	15,500	38		4 30	7
May,	8	7,500	38		5 10	8 6
June,	8	8,000	40		5 50	8 30
July,	10	100,000	45		8 30	11 20
August,	9	5,700	27		6 0	13 9
September,	6	85,000	70		13 30	11 4
October,	10	25,000	43		11 0	15 15
November,	6	2,500	24		6 30	16 6
December,	0					
	95	282,000	423		109 15	
Per fire,			4·45			

From these notes it appears that the average use of hydrants is about four per fire, and the average length of hose per hydrant somewhat less than 450 feet, the average length of time for fires being 2·71 hours, though the variations in such duration are considerable, as are also the respective amounts of damage.

The use, as here shown, of about 1700 feet of hose per fire, presents in resultant, excessive friction, a strong argument in favor of shorter intervals between hydrants, while it forcibly illustrates the superior effects of prompt service from improved hydrants and short lengths of hose; and herein is contained the system of improvement which a better fire service evidently demands.

This improvement, in our opinion, should consist in the subdivision of the present fire districts of any large city, into small sections through which the average running time, from hose station to extreme limit should not exceed three minutes, for a small, compact hose reel and hand-cart, which two men could easily manage; in addition, wherever it could conveniently be done, by arrangement with public spirited house occupants, or insurance stockholders, opposite hydrants, a couple of lengths of hose might be deposited in houses well known to the police and otherwise specially designated as such store houses; this need not be done on every block, but at intervals of several blocks, so as to control spaces not exceeding 1500 feet in length, and in some localities the interspaces might be greater; advantage should be taken of the present engine hose houses for use as such auxiliary stations.

In this way, by the employment of men, specially engaged in such preliminary fire service, who are always in the immediate vicinity of an alarm, and can know of it as readily as the police who now report fires to the nearest telegraph station, which reports to the proper office for a district alarm, and who can act in advance of the fire

watchmen in their towers, the means will be provided for a prompt and effective application of remedies which are all the more effective from early use. These firemen, who might very properly be members of the district police, would find no lack of willing assistants, since fire alarms have a very peculiar eloquence to next door neighbors and are apt to speak in imperative moods. With such appliances at hand, the principal of prompt remedy might be fully developed, and in the case of more serious fires, the first engine on the ground would find a hose supply ready for its pumps. As this plan increases the number of hydrants, it would reduce the lengths of hose in use, and for the same number of engines at work, there would be a more abundant supply with less cleaning to do afterward. This last item is paid for now, at a very dear rate, and certainly would not cost any more, under the new arrangement; but the stock of hose would have to be increased and the number of hydrants, at a cost which the first fire prevented, would probably more than balance.

The expense of such an arrangement, which ensures one or more hydrant streams, within one quarter the time now wasted, and which will reduce the cost of insurance, the aggregate damage, and the contingencies of life lost, while it promotes a general sense of security, will be affected by the details of its application. With a paid fire department, as at Boston, the expense need not be increased, and by allotting a portion of the police force to this service, as organized in New York and Brooklyn, the increase of cost cannot be large, and one local advantage will ensue, in having a policeman or two, always located and easily found. Whether any such additional expense shall be borne by insurance companies or not, is a question of municipal policy which pertains to the entire use of water supply for insured buildings, and which admits arguments on both sides, since improved water supply always has been met by reduced insurance premiums, and all fire losses, whither indemnified or not to property owners, always exhaust a certain taxable property, which represents its proportion of municipal income and wealth.

Whatever may be the water pressure, it is evident that this addition to the method of fire service would be followed by immediate and important benefits; at the same time, it is evident that such auxiliary service might be made much more valuable, if all the details of distribution service were arranged with a distinct adaptation to such a system. What this line of improvement is, will therefore be properly discussed in the remarks which follow on the defects of distribution, and their correctives, and the progress, defects, and improvements of fire hydrants.

(To be Continued.)

For the Journal of the Franklin Institute.

The Radial Paddle-Wheel. By JOHN D. VAN BUREN, Jr., C. E., U. S. Naval Engineers.

(Continued from page 25.)

The Centre of Horizontal Effort.

Each elementary area $d\,r$ impinges horizontally against the water with a relative velocity equal to $(r\,w\,\cos\varphi - v)$, and has an effective area opposed to the resistance in such direction equal to its vertical projection $d\,r\,\cos\varphi$. Hence, as before, the resistance opposed to the motion of the paddle in a horizontal direction, is

$$\int (rw\cos\varphi - v)^2 dr\cos\varphi \quad . \quad . \quad (a)$$

and the sum of the moments about c is, for all the paddles,

$$\Sigma\int (rw\cos\varphi - v)^2 r\,dr\cos^2\varphi \quad . \quad . \quad (b)$$

$r\cos\varphi$ being the arm of each elementary force.

Now let X = distance from centre of shaft to point of application of resultant of all the horizontal efforts or resistances of the different paddles, *i. e.*, to the centre of horizontal effort of the wheel. Then since the moment of the resultant is equal to the sum of the moments of the components, we have

$$X\Sigma\int (rw\cos\varphi - v)^2 dr\cos\varphi = \Sigma\int (rw\cos\varphi - v)^2 r\,dr\cos^2\varphi \quad (8)$$

or

$$X = \frac{\Sigma\int (rw\cos\varphi - v)^2 r\,dr\cos^2\varphi}{\Sigma\int (rw\cos\varphi - v)^2 dr\cos\varphi} \quad . \quad . \quad (9)$$

where Σ signifies that the sum of all similar terms is taken.

Now putting N_1, N_2, &c., for the variable factors of the numerator, and D_1, D_2, D_3, &c., for the variable factors of the denominator, there results

$$X = \frac{N_1\cos^2\varphi_1 + N_2\cos^2\varphi_2 + \&c.}{D_1\cos\varphi_1 + D_2\cos\varphi_2 + \&c.} \quad . \quad . \quad (10)$$

where

$$N = \int_{R_1}^{R_2} (r\,w\cos\varphi - v)^2\,r\,dr, \text{ and } D = \int_{R_1}^{R_2} (r\,w\cos\varphi - v)^2\,dr \quad (11)$$

Now for N and D we may use proportional quantities, and to find such we have

$$\frac{N}{D} = \frac{\int (r\,w\cos\varphi - v)^2\,r\,dr}{\int (r\,w\cos\varphi - v)^2\,dr} \quad . \quad . \quad . \quad (12)$$

This differs from (5) only in the position of cos ϕ (a constant); and therefore, $\cos^2\phi$ in (6) being transferred from the last terms of numerator and denominator to the first terms of the same gives (12), or,

$$\frac{N}{D} = \frac{3(R_2^4 - R_1^4)\cos^2\varphi - 8(R_2^3 - R_1^3)R_2 m\cos\varphi + 6(R_2^2 - R_1^2)R_2^2 m^2}{4(R_2^3 - R_1^3)\cos^2\varphi - 12(R_2^2 - R_1^2)R_2 m\cos\varphi + 12(R_2 - R_1)R_2^2 m^2} \quad (13)$$

Therefore by taking for N the numerator, and for D the denominator, of (13), calculated respectively for the different paddles making the respective angles with the vertical of φ_1, φ_2, φ_3, &c., and substituting these values of N and D for N_1, N_2, &c., D_1, D_2, &c., in (10), we shall find X. But some parts of a paddle may have a less *horizontal* velocity than v; and then the resistance will evidently be *negative*, the water impinging against the paddle instead of the reverse. This negative sign will not appear in the value of N or D, for the *squares* of ($r w \cos\varphi - v$) will always be positive. We have therefore to determine that portion of the paddle which has less horizontal velocity than v, and consider the paddle as two distinct paddles, one being the said portion having less horizontal velocity than v. This dividing line is readily found; for it is determined by the equation.

$$R w \cos\varphi = v = m R_2 w$$

or

$$R = \frac{m R_2}{\cos\varphi} \quad . \quad . \quad . \quad (14)$$

R being its distance from C. For the upper portion of the paddle, considered as a distinct paddle, R must be put for R_2 in the expressions for N and D', and for the lower portion, considered as a distinct paddle, R must be put for R_1. This is the only change necessary.

Modulus of the Radial Paddle-Wheel.

The modulus is the ratio between the useful work and the total work of the wheel.

The total work of the wheel is the sum of all the normal resistances acting with a velocity equal to the rotary velocity of that point at which we may consider all the normal resistances to act as a single force producing the same moment about c.

The useful work is the sum of the horizontal resistances acting with a velocity $v = m R_2 w$.

Let H = distance from centre of shaft to the point at which all the normal resistances may be considered to act as a single force.

$$\therefore H \Sigma\int (rw - v\cos\varphi)^2 d r = \Sigma \int (rw - v\cos\varphi)^2 r dr$$

or

$$H = \frac{\Sigma\int (r w - v\cos\varphi)^2 r dr}{\Sigma\int (r w - v\cos\varphi)^2 dr} \quad . \quad . \quad . \quad (a)$$

The point determined by H has a rotary velocity of H w; hence the work of the normal resistances is

$$\text{H}w\,\Sigma\int(rw-v\cos\varphi)^2\,dr$$

The work of the horizontal resistances is

$$v\,\Sigma\int(rw\cos\varphi-v)^2dr\cos\varphi=m\text{R}_2w\Sigma\int(rw\cos\varphi-v)^2dr\cos\varphi \quad (b)$$

$$\therefore \text{Modulus}=\text{M}=\frac{m\,\text{R}_2}{\text{H}}\cdot\frac{\Sigma\int(rw\cos\varphi-v)^2\,dr\cos\varphi}{\Sigma\int(rw-v\cos\varphi)^2\,dr}$$

or (a)

$$\text{M}=m\text{R}_2\frac{\Sigma\int(rw\cos\varphi-v)^2\,dr\cos\varphi}{\Sigma\int(rw-v\cos\varphi)^2\,rdr}$$

$$=m\,\text{R}_2\frac{\text{D}_1\cos\varphi_1+\text{D}_2\cos\varphi_2+\&\text{c.},}{\text{N}'+\text{N}''+\&\text{c.},} \quad . \quad . \quad (15)$$

when N = integral of the numerator of (5), or,

$$\text{N}=3(\text{R}_2{}^4-\text{R}_1{}^4)-8(\text{R}_2{}^3-\text{R}_1{}^3)\,\text{R}_2\,m\cos\varphi+6(\text{R}_2{}^2-\text{R}_1{}^2)\,\text{R}_2{}^2\,m^2\cos^2\varphi \quad (16)$$

and N′, N″, &c., are calculated from (16) for the different paddles by putting for φ the values φ_1, φ_2, &c., respectively.

Example. Let seven paddles be submerged, making the following angles with the vertical: $\varphi_1=30°=\varphi_7$, $\varphi_2=20°=\varphi_6$, $\varphi_3=10°=\varphi_5$, $\varphi_4=0°$. Let $\text{R}_2=10$ feet, $\text{R}_1=8$,—therefore $m=\cdot8$. Required the modulus of the wheel.

We have to calculate D_1, D_2, &c., from the denominator of (13), and N′, N″, &c., from (16). These values substituted in (15) give the required answer.

The two paddles which make the angle 30° with the vertical, however, will contain portions which have less horizontal velocity than v or the velocity of the vessel. Hence, we must consider these paddles each as two distinct paddles, the upper portions giving a negative resistance or *drag*. To find the dividing line we have

$$\text{R}=\frac{m\,\text{R}_2}{\cos\varphi}=\frac{\cdot8\times10}{\cos30°}=9\cdot238\text{ feet.}$$

For the upper portion, therefore, $\text{R}=9\cdot238$ takes the place of R_2, and for the lower portion, $\text{R}=9\cdot238$ takes the place of R_1, in the formulas. The calculations are made in the following tabular form.

Angles.	1 $4(R_2^2-R_2^2)$ (Logs.)	2 $\cos^2\phi$ (Logs.)	Product of 1 and 2.	3 $12(R_2^2-R_1^2)R_2$ (Logs.)	4 $m\cos\phi$ (Logs.)	Product of 3 and 4.	$12(R_2-R_1)R_2^2m^2$	Values of D.
0°	3·0350293	20·	1084·	3·3579348	9·9030900	1824·	768·	$D_4 = 28{\cdot}00.$
10	"	19·9867030	1051·32	"	9·8964415	1796·29	"	$D_5 = 23{\cdot}03 = D_3.$
20	"	19·9459716	957·20	"	9·8760758	1714.	"	$D_2 = 11{\cdot}20 = D_6.$
30	2·3757002	19·8750612	178·14	2·6822534	9·8406206	333·33	155·99	$D_1 = -{\cdot}80 = D_7.$
30	2·9276167	"	634·86	3·2108932	"	1125·94	499·42	$D_1 = 8{\cdot}34 = D_7.$

To find $D_1\cos\varphi + \&c.$

	Angles.	D (Logs.)	Cos ϕ (Logs.)	Products.
	0°			28·00=28.
	10	1·3622939	9·9933515	22·68×2=45·36.
$(D_7 + D_7)$	20	1·0492180	9·9729858	10·54×2=21·08.
	30	·8773713	9·9375306	6·53×2=13·06.
				∴ $D_1\cos\phi_1 + \&c. = 107{\cdot}50.$

To find $N' + N'' + \&c.$

Angles.	$3(R_2^4-R_1^4)$	$8(R_2^3-R_1^3)R_2m$ (Logs.)	Cos ϕ (Logs.)	Product.	$6(R_2^2-R_1^2)R_2^2m^2$ (Logs.)	$\cos^2\phi$ (Logs.)	Product.	Values of IV.
0°	10317	4·2391493	10·000000	17344·	3·8630848	20·	7296.	$N^{IV} = 260{\cdot}00.$
10	"	"	9·9933515	17080·5	"	19·9867030	7076.	$2N^{III} = 625{\cdot}00 = 2N^{V}$
20	"	"	9·9729858	16298·00	"	19·9459716	6442·3	$2N^{II} = 922{\cdot}6 = 2N^{VI}.$
30	"	"	9·9375306	15020·4	"	19·8750612	5472.	$2N^{I} = 1537{\cdot}2 = 2N^{VII}.$
								∴ $N^{I} + \&c. = 3353{\cdot}80$

Hence for seven paddles $M = \dfrac{m R_2 [D_1\cos\varphi + \&c.]}{N' + N'' + \&c.} = {\cdot}26$, *i. e.*, loss ·74

" " five " $M = {\cdot}42$, *i. e.*, loss ·58.

" " three " $M = {\cdot}66$, *i. e.*, " ·34.

Remarks on the Results.

By the result it will be seen that the loss when *seven* paddles are submerged is 78 per cent., by slip and oblique action; when *five* are submerged the loss is 58 per cent.; and when *three* are submerged the

loss is 34 per cent. The great loss in the first two cases will be readily accounted for when we consider: that the *normal resistances* besides having greater velocities than the *horizontal resistances*, *increase* very rapidly as the paddles recede from the vertical,—the paddle nearest the surface having the greatest normal resistance, since it is less affected by the velocity v,—while the *horizontal resistances diminish* very rapidly at the same time; that the slip is much greater for the inner portions of the paddles than for the outer; that the upper paddles while experiencing great *normal* resistances are scarcely effective; that the vertical *velocities* are not affected by v, and therefore the vertical resistances are correspondingly greater.*

It will be observed, that if the *dip* of the wheel is diminished the slip will increase, the law of which increase can only be ascertained by experiment. It is necessary, therefore, to fall back upon experiment to ascertain the best arrangement for the paddles. We, however, see that under the best circumstances considerable power is lost by the *radial* paddle-wheel,—this loss which is almost wholly obviated in the *feathering* paddle-wheel.

NOTE.—These results are somewhat modified by reason of the change of position of the paddles; but the extreme positions being only 5° apart, the influence on the result is small. For any extreme case a mean of the results for the two extreme positions would give a more correct answer.

* The above losses are increased by having the paddles wider.

For the Journal of the Franklin Institute.

General Problem of Trussed Girders. By DE VOLSON WOOD, Prof. of C. E., University of Michigan.

(Continued from Vol. xlviii, page 386.)

Before proceeding with the analysis, I wish to make an observation upon the latter part of the preceding article. I observed that Tredgold's rule was not generally reliable, but I find upon further reflection that it may be made essentially the same as Robison's, and hence may be reliable. The literal application of the rule taken in connexion with the example which he gives, will lead to the results which I indicated. But if we refer to fig. 19, Vol. xlviii, p. 385 and in it consider that the reaction of the support at A—and not the weight P—is the *straining force*, and then apply Tredgold's rule, we shall find correctly the strains on A A and A d. Now consider the strain on A d, (which is transmitted from A to d), as the *straining force*, and we shall get correct results for $d\,d$ and the second brace (tie). *So proceed to the point where the shearing stress is zero.* This method of using the rule makes it essentially the same as Robison's, but as the latter is more explicit, I should prefer it.

On page 386 there is a grammatical error caused by an omission. It should read: "The limitations to which I wished to refer, are, *we must not pass the point where the vertical shearing stress is zero, or having passed it, we must observe that the strain on the brace immediately following has a contrary sign from that determined by the rule.*"

18°. *Let the axis of* Y *intersect more than three bars.* Let us first take

a simple case. Suppose that the chords are parallel, and that both the diagonal bars, as shown in figure 20, Plate II, resist strains. Take a section at g, in which Y intersects the upper and lower chords, and the inclined bars $g\,a$ and $b\,f$.

Let F_2 = the strain on $g\,a$ (compressive).
F_3 = " " $f\,b$ (tensive)

and the other notation as before given.

Then we find for the first members of equations (4) and (5),

$$\Sigma F \cos \alpha = H + F_2 \sin \theta - F_3 \sin \theta - H_1$$
$$\Sigma F \cos \beta = F_2 \cos \theta + F_3 \cos \theta$$
$$\Sigma F \cos \gamma = 0$$

and couple around $Z = H_1 D + F_3 D \sin \theta$

If we also suppose that all the forces are vertical, or perpendicular to the chords; then will the values of the second members of (4) and (5) become the same as the second members of (12); hence we have the following equations:

$$\left.\begin{aligned} H + F_2 \sin \theta - F_3 \sin \theta - H_1 &= 0 \\ F_2 \cos \theta + F_3 \cos \theta &= V - \Sigma_o^x P^* \\ H_1 D + D F_3 \sin \theta &= V_{xI} - \Sigma_o^x P_x \end{aligned}\right\} \quad . \quad (51)$$

Here we have four unknown quantities with but three equations; hence other conditions must be established before the problem can be solved.

It is not easy to assign the conditions which will be realized in practice. If both bars were placed side by side and inclined the same as $a\,g$; or if in their present position they were fixed with equal care, it might be safe to assume that they sustain equal strains; or $F_2 = F_3$. This condition will enable us to solve the problem. But it is difficult to fix the bars so as to realize this condition; and hence it is, that in computing such structures, or indeed compound structures generally, we assume that one of the bars sustains nearly or quite all the strain that should fall upon both, and that the other is introduced for additional security. If the bars were perfectly rigid, one or the other would be obliged to sustain all the strain; but because they are elastic, the elongation or compression of one, will tend to produce increased strains on the other. Hence, there is a constant tendency to an equality of strains on the inclined bars. Those who are familiar with the principles of bridge construction will observe that these remarks apply with equal, if not greater force to trusses which are made by combining the arch with the truss of parallel chords; of which the Burr Truss is a good example. See figure 21, Plate II. For a description of this truss see Mahan's Civil Engineering, p. 241; also Haupt on Bridge Construction.

Although such combinations are often more practical than the simple forms, yet they cannot be considered as scientific; for the strains on the several parts cannot be rigidly computed. In iron structures this is a serious objection, while in wooden ones it is not; for the cheapness of the latter material makes the size of the parts of secondary

*It will be observed that I omit the subscript of x because I deem its use no longer necessary.

LIBRARY

importance, and hence it is not economical to compute too closely; but the cost of the former material makes it economical to use as little as possible, having due regard to safety.

Assuming, in the case before us, that $F_2 = F_3$, and equations (51) become

$$\left.\begin{aligned} H - H_1 &= 0 \\ 2F_2 \cos\theta &= V - \Sigma_o^x P \\ H_1 D + DF_2 \sin\theta &= V_{x_1} - \Sigma_o^x P_x \end{aligned}\right\} \quad . \quad . \quad (52)$$

From equations (52) we see:

1st. That the strains on the upper and lower chords equal each other.

2d. That the diagonal bars sustain the shearing stress;

and by comparing the third of (52) with the third of (40), or (45) we see,

3d. That the strain on the lower chord is less than it would be if bf were omitted.

If the axis of Y passes through a vertical bar without intersecting the inclined ones, θ becomes zero, and as but one bar is intersected we omit the factor 2, and (52) becomes,

$$\left.\begin{aligned} H - H_1 &= 0 \\ F_2 &= V - \Sigma_o^x P \\ H D &= V_{x_1} - \Sigma_o^x P_x \end{aligned}\right\} \quad . \quad . \quad (53)$$

If the axis of Y be taken just at the right of id, so as to intersect only the upper and lower chords, then will $F_2 = 0$; and (52) becomes,

$$\left.\begin{aligned} H &= H_1 \\ 0 &= V - \Sigma_o^x P \\ H D &= V_{x_1} - \Sigma_o^x P_x \end{aligned}\right\} \quad . \quad . \quad . \quad (54)$$

We must not infer from the second of these, that $V = \Sigma_o^x P$; but rather that there is a vertical resistance in the chords equal F_2 in (53); to sustain the vertical shearing. I shall refer to this hereafter.

If the inclined bars are capable of resisting both tension and compression, the vertical bars will be unnecessary, and the truss may take the form of figure 22, Plate II. Town's Lattice is of this form, only that each piece is made to cross several which incline the opposite way, as shown in figure 23, Plate II. For a description of this lattice see Mahan's Civil Engineering, page 174, and Silliman's Journal, Volume xxxviii, 1st Series, p. 276.

To analyze it suppose that Y intersects n inclined bars which incline the same way; then will $2n$ be the total number which it intersects. We will neglect the influence of the inclined bars in relieving the strains on the chords; then by inspecting equations (52) we may write the following:

$$\left.\begin{aligned} H &= H_1 \\ 2n F_2 \cos\theta &= V - \Sigma_o^x P \\ H D_1 &= V_{x_1} - \Sigma_o^x P_x \end{aligned}\right\} \quad . \quad . \quad . \quad (55)$$

If the load is uniform, and extends from end to end, we have from (21) and (55),

$$\left.\begin{aligned} H &= H_1 \\ 2n\, F_2 \cos\theta &= \tfrac{1}{2}\, w\, (L - 2x_1) \\ H_1 D &= \tfrac{1}{2}\, w\, (L x_1 - x_1^2) \end{aligned}\right\} \quad . \quad . \quad . \quad (56)$$

For the extremities $x_1 = 0$ and we have

$$\left.\begin{aligned} 2n\, F_2 \cos\theta &= \tfrac{1}{2}\, w\, L = \tfrac{1}{2} W \\ H &= H_1 = 0 \end{aligned}\right\} \quad . \quad . \quad . \quad (57)$$

For the middle section $x_1 = \frac{1}{2} L$ and we have

$$\left.\begin{aligned} H = H_1 &= \tfrac{1}{8}\, w\, L^2 = \tfrac{1}{8}\, W\, L \\ F_2 &= 0 \end{aligned}\right\} \quad . \quad . \quad . \quad (58)$$

There are cases in which Y may intersect more than three bars, and yet be determinate. This is the case with figure 19, page 385, in which if Y intersects the bars less inclined, it will generally intersect five bars. It may be made to intersect three bars by using a system of oblique co-ordinates; or even, by a system of rectangular co-ordinates in which X will be inclined to the parallel chords. In this way the problem becomes determinate.

19° *Let all the bars be horizontal and resist directly as their distance from a horizontal line.*

It is generally supposed that this is the law which governs the resistance of beams when subjected to transverse strains. Several of the preceding equations give $H - H_1 = 0$; from which we see, that if there is tension on one side of a beam, there must be compression on the other, and that between them there will be a line of no strain. This is called the *Neutral Axis*, and a plane of such fibres is called a *Neutral Plane*.

Let A B, figure 24, Plate II, be a beam which is subjected to a transverse strain, and let us consider the effect upon any section, as C D.

Take the origin of co-ordinates at any point in the plane section, and let the axis be the same as in the first of this series of articles, only we will let Y be positive downwards. Since the fibers are parallel to X we have $a = 0$ or $180°$, $\beta = 90°$, $\gamma = 90°$, in (4) and (5) and they become,

$$\Sigma \pm F = -\Sigma\, P \cos a,\ 0 = -\Sigma\, P \cos b,\ 0 = -\Sigma P \cos c\ ; \quad . \quad . (59)$$

$$0 = -\Sigma\, P\ (y \cos c - z \cos b),\ \Sigma F_z = -\Sigma\, P\ (z \cos a - x \cos c),$$

$$\Sigma \mp F y = -\Sigma\, P (x \cos b - y \cos a), \quad . \quad . \quad (60)$$

If the applied forces are parallel to Y, we have $a = 90°$, $b = 0$ or $180°$, and $c = 90°$, and (59) and (60) become,

$$\Sigma \pm F = 0,\ 0 = \Sigma \pm P,\ 0 = 0\ ; \quad . \quad . \quad . \quad . \quad . \quad (61)$$

$$0 = \Sigma\, P z,\ \Sigma\, F z = 0,\ \Sigma\, F y = \Sigma\, P x \quad . \quad . \quad . \quad . \quad (62)$$

These equations are worthy of especial notice, as they contain the *theory* of resistance of beams as used in practice. The signification of each of the expressions in (61) and (62), are given in number 3°,

page 232 of the preceding volume. We will now examine their interpretation.

The first, $\Sigma \pm F = 0$, is the DIRECT STRESS, and shows *that the total compressive strains on one side of the neutral axis, equal the total tensive strains on the other side.* I shall make use of this principle hereafter to find the position of the *neutral axis.*

The second shows that the sum of the upward equals the sum of the downward forces. But, as the distribution of the applied forces is arbitrary, this condition may not be established. For instance, in the figure, we suppose that there is only one force acting at the free end, and the equation becomes $0 = P$. What is the interpretation in this case? The equation evidently reduces to an absurdity; hence, we infer,

1st. *That any number of parallel fibres acting independently, and resisting only longitudinal strains, cannot sustain a force which acts perpendicular to them;* but as beams do sustain transverse forces, and as the fibres do not act independently of each other, we infer,

2d. *That in practice a beam is capable of resisting a transverse shearing stress in addition to the extension and compression of the fibres.*

The problem, then, which is stated in number 19° cannot be realized without this additional principle.

Calling this shearing stress Ss, and we have

$$Ss = \Sigma P \quad . \quad . \quad . \quad (63)$$

The third of (61) is simply a true equation.

The first of (62), which is the *Twisting* force, is absurd, except when the sum of the moments which tend to twist the beam in one direction equals those which twist the opposite way. If these forces are in the plane YX, then will $z = 0$, and the equation becomes $0 = 0$; but if a single force has a lever arm, z, the equation becomes $0 = Pz$. To resist this moment there is really a shearing stress, which has not been noticed in the analysis, and is called *a resistance to torsion.* In order, then, to find the true value of this resistance, we must know the laws which govern it. They are,

1st. The ultimate resistance of the most remote fibre from the neutral axis is constant:

2d. The strains upon the fibres vary directly as their distance from the neutral axis:

3d. The angle of torsion varies directly as the twisting force, and as the distance between the sections.

From these we may establish the equations for torsion.

The second of (62) shows that there is no tendency to twist about the axis of Y. It is really the *resistance* to torsion; and we have practically $\Sigma P_x = \Sigma F_x$.

The *third* shows that the sum of the moments which tend to bend the beam about the axis of z, equals the moments of the resisting forces. We will now develop this expression.

Let a = OE = the distance between the axis of X and the neutral plane,

R = the strain on the unit of fibres which is most remote from the neutral axis,

R $dy\,dz$ = the strain on *the fibre* which is most remote from the neutral axis,

d_1 = the distance of the most remote fibre from the neutral axis;

$(a + y)$ is the distance from the origin, of *any* fibre which is below the neutral axis, and

$(a - y)$ the corresponding distance above.

Then from the law of resistance which is stated in number 19°, we have

$$d_1 : a \pm y :: \text{R}\,dy\,dz : \text{strain on any fibre} = \frac{\text{R}}{d_1}(a \pm y)\,dy\,dz.$$

The lever arm of this strain is $a \pm y$; hence, *the moment of strain* of a single fibre is

$$\frac{\text{R}}{d_1}(a \pm y)^2 dy\,dz$$

If the origin be taken upon the neutral axis, a becomes zero, and we have, after integrating so as to include the whole area,

$$\Sigma\,\text{F}\,y = \frac{\text{R}}{d_1}\iint y^2\,dy\,dz = \Sigma\,\text{P}\,x$$

The expression, $\iint y^2\,dy\,dz$, is the moment of inertia of the section. Calling it I, and we have

$$\text{I} = \iint y^2\,dy\,dz \quad . \quad . \quad (64)$$

$$\frac{\text{R}}{d_1}\text{I} = \Sigma\,\text{P}\,x \quad . \quad . \quad (65)$$

Such is the relation between the strains and applied forces. If R is made equal to the strength of a unit of fibres, then (65), if applied to the *dangerous section*, i. e. the section most liable to break, will give the strength of a beam. Equation (63) must also be satisfied.

For example, suppose that a rectangular beam is supported at the ends, and sustains a weight P, at the middle. Let b = the breadth, and d the depth of the beam, and l its length.

$$\text{Then } \text{I} = \int_0^b \int_{-\frac{1}{2}d}^{+\frac{1}{2}d} y^2\,dy\,dz = \tfrac{1}{12}\,b\,d^3,$$

$d_1 = \frac{1}{2}d$, and for the middle section,*

$$\Sigma\,\text{P}x = \tfrac{1}{2}\text{P} \times \tfrac{1}{2}l = \tfrac{1}{4}\text{P}l$$

$$\therefore \tfrac{1}{6}\,\text{R}\,bd^2 = \tfrac{1}{4}\,\text{P}\,l$$

The relation between the applied forces and resistances may also be

*It will be shown hereafter that according to the hypothesis which we are considering, that the neutral axis passes through the centre of gravity of the sections; hence in the rectangle $d_1 = \frac{1}{2}d$.

found in terms of the *modulus of elasticity*. In figure 26, Plate II, let the sections C D and E H be parallel before the beam is bent, but after it is bent they will be normal to the neutral axis K L, and will meet if prolonged, in O. Let K L be indefinitely small $= dx$, then will O K $=$ O L $= \rho =$ the radius of curvature of the neutral axis. Prolong these radii until K M $=$ L N $= \rho$.

The modulus of elasticity may be defined to be a force which will elongate a bar to double its original length, provided the elasticity does not change. Then if E produces the elongation Q N on the fibre M Q; while R produces the elongation E F on C E; we have from the similarity of triangles, since the elongations are proportional to the strains,

$\frac{E}{\rho} = \frac{R}{d_1}$ which in (65) gives

$$\frac{E\,I}{\rho} = \Sigma P x \quad . \quad . \quad . \quad (66)$$

This equation is true only within the elastic limits, and hence, for small curvatures. For this case we may deduce an approximate formula which will be more convenient for use.

From Calculus, we have $\rho = \frac{(dx^2+dy^2)^{\frac{3}{2}}}{d^2y\,dx}$

$$= \frac{\left(1+\frac{dy^2}{dx^2}\right)}{d^2y} dx^2 = \frac{dx^2}{d^2y} \text{ nearly.}$$

and our equation becomes,

$$E\,I\frac{d^2y}{dx^2} = \Sigma P x \quad . \quad . \quad . \quad (67)$$

Out of the vast number of problems to which this equation may be applied, I will select one which yields a fruitful discussion.

EXAMPLE. *Let a prismatic beam be fixed at one end, supported at the other, and a weight* P *be applied at any point; it is required to find the equation of the neutral axis, and discuss the problem.*

One end may be fixed by being firmly imbedded in a wall, as in fig. 27, Plate II, or it may extend over a support and a weight P_1 applied which shall make the curve horizontal over the support, as in figure 28, Plate II, or the beam may rest on three supports, and two equal forces applied at equal distances from the middle one, as in fig. 29, Plate II. The discussion is the same in either case.

Let A B $= l =$ the length of the part considered.

V $=$ the reaction of the support at B.

$nl =$ A C.

Take the origin at A, and let A C be the abscissa of the point of application of the force P. There will be two curves, distinct in their nature; one A D, the other D B. We may conceive that the curve D B is caused by the force V; and A D, by V and P; or generally, as was

observed in the early part of these articles, we may consider all the forces at the right (or left) of a section as producing the effect.

First consider the curve A D.

Observing that x is the abscissa of any point of the curve, and we have $(nl-x)$ for the lever arm of P, and $(l-x)$ for the lever arm of V; and by observing the proper signs for the forces, we immediately have

$$\Sigma Px = P(nl-x) - V(l-x), \text{ hence equation (67) becomes,}$$

$$E I \frac{d^2y}{dx^2} = P(nl-x) - V(l-x) \quad . \quad . \quad (68)$$

multiply by dx and integrate, and we have,

$$E I \frac{dy}{dx} = P(nlx - \tfrac{1}{2}x^2) - V(lx - \tfrac{1}{2}x^2) \quad . \quad . \quad (69)$$

and again, $$E I y = P(\tfrac{1}{2}nlx^2 - \tfrac{1}{6}x^3) - V(\tfrac{1}{2}lx^2 - \tfrac{1}{6}x^3) \quad . \quad (70)$$

The constants of integration are zero; for $\frac{dy}{dx}$ and $y = 0$ for $x = 0$.

Let i = the inclination of the curve at D, and making $x = nl$ in 69) we have,

$$\frac{dy}{dx} = \tan i = \left[\tfrac{1}{2}n^2 P - (n - \tfrac{1}{2}n^2) V\right] \frac{l^2}{E I} \quad . \quad (71)$$

Let f = the deflection at D, and making $x = nl$ in (70) and it becomes,

$$y = f = \left[\tfrac{1}{3}n^3 P - (\tfrac{1}{2}n^2 - \tfrac{1}{6}n^3) V\right] \frac{l^3}{E I} \quad . \quad (72)$$

Next consider the curve D B.

The origin remaining the same, we observe that x will be the abscissa of any point on D B; and the lever arm of V will be $(l-x)$; hence equation (67) becomes,

$$E I \frac{d^2y}{dx^2} = -V(l-x) \quad . \quad . \quad (73)$$

Integrating this equation twice, and finding the constants by observing that $\frac{dy}{dx}$ = tang. i for $x = nl$, and $y = f$ for $x = nl$, and placing the results equal (71) and (72), and we immediately find

$$E I \frac{dy}{dx} = \tfrac{1}{2} P n^2 l^2 - (lx - \tfrac{1}{2}x^2) V \quad . \quad . \quad (74)$$

$$E I y = (\tfrac{1}{2}x - \tfrac{1}{6}nl) P n^2 l^2 - (\tfrac{1}{2}lx^2 - \tfrac{1}{6}x^3) V \quad . \quad (75)$$

To find the re-action, observe that $y = 0$ for $x = l$ in (75), and we find,

$$V = \tfrac{1}{2} P n^2 (3-n) \quad . \quad . \quad (76)$$

For instance, if $n = \frac{1}{2}$, $V = \frac{5}{16} P$

if $n = 0{\cdot}5858$, $V = 0{\cdot}4145\ P$

By substituting the general value of V in the preceding equations,

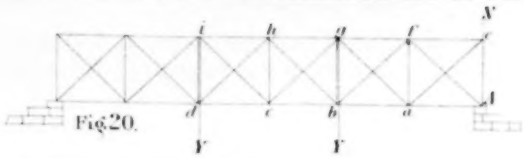


Fig. 20.

Fig. 22.

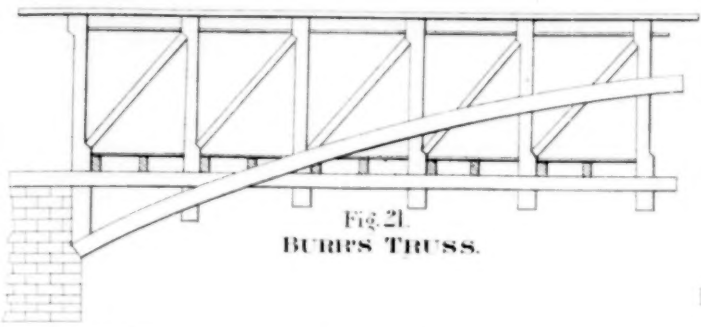


Fig. 21.

BURR'S TRUSS.

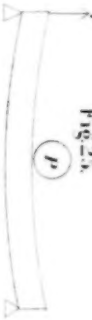


Fig. 25.

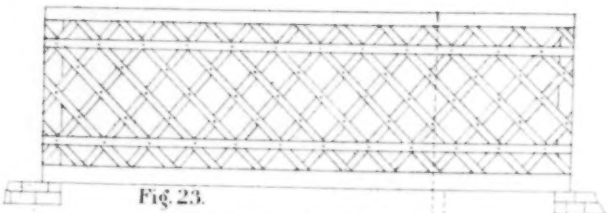
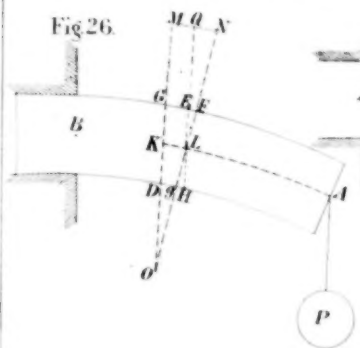


Fig. 23.

TOWNE'S TRUSS

Y

Fig. 26.



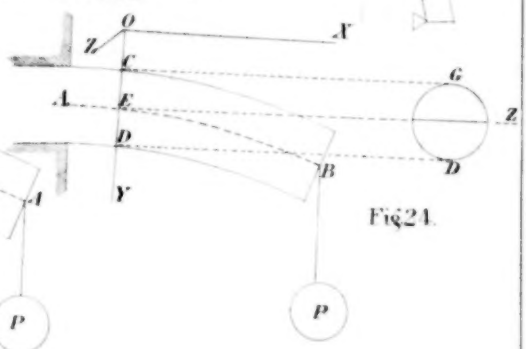


Fig. 24.

Fig. 27.

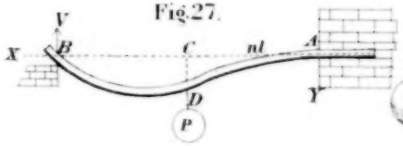


Fig. 28.

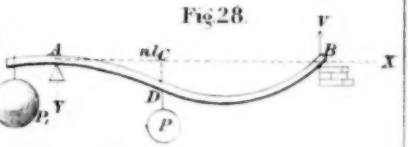


Fig. 29.

Jas. McGuigan Lith. Phila.

they become completely determined; and we shall have for the curve A D,

$$E\,I\,\frac{d^2y}{dx^2} = P\left[nl-x-\tfrac{1}{2}\,n^2\,(3-n)\,(l-x)\right] \quad . \quad (76)$$

$$\frac{dy}{dx} = \frac{P}{4EI}\left[4nlx-2x^2-n^2(3-n)\,(2lx-x^2)\right] \quad . \quad (77)$$

$$y = \frac{P}{12EI}\left[6nlx^2-2x^3-n^2\,(3-n)\,(3lx-x^3)\right] \quad . \quad (78)$$

and for the curve D B,

$$E\,I\,\frac{d^2y}{dx^2} = -\tfrac{1}{2}\,Pn^2\,(3-n)\,(l-x) \quad . \quad . \quad (79)$$

$$\frac{dy}{dx} = \frac{Pn^2}{4EI}\left[l^2-(3-n)\,(2lx-x^2)\right] \quad . \quad (80)$$

$$y = \frac{Pn^2}{12EI}\left[(6x-2nl)\,l^2-(3lx^2-x^3)\,(3-n)\right] \quad . \quad (81)$$

To find the points of maximum strain. The second members of (76) and (79) give the moments of strain, and hence the greatest strain will be found by making the second members a maximum.

But in a strict mathematical sense these have no maximum. For instance, taking equation (76), we may find that value of x which will make the second member zero. From this point the function will increase indefinitely both ways—with contrary signs—as x increases or decreases. We see then, that the greatest strain on this part of the curve within the limits of the problem, will be at the fixed end and at the point of application of the force. For these points we make $x=0$, and $x = nl$ in (76) and we have for the strain at the fixed end

$$\Sigma Px = \tfrac{1}{2}\,Pl\left[\,2n-3n^2+n^3\,\right] \quad . \quad . \quad (82)$$

for the strain at the point of application

$$\Sigma Px = \tfrac{1}{2}Pln^2\left[\,-3+4n-n^2\,\right] \quad . \quad (83)$$

Now considering the curve D B, and we observe from (79) that the strains increase (negatively) from the support to the point of application; hence the greatest strain is at that point, and may be found by making $x = nl$ in that equation. This will reduce it to the same as (83). *Hence* (82) *and* (83) *give the values of the greatest strains for any point of application of the force.*

Now suppose P moves along on the beam from B towards A; the strains directly under P will increase up to a certain point, and then decrease until it reaches A. *It is proposed to find the position of* P *when it produces the maximum strain*; i. e. greater than if applied at any other point. To do this we have only to find the maximum of (83) by the ordinary rules of calculus.

$$\therefore D = 0 = -6n^2+12n^2-4n^3$$

$$\therefore n = 0{\cdot}634+,$$

or more than half the length of the beam from the fixed end. This value in (83) gives

$$\Sigma Px = Pl \times 0\ 174+,$$

and in (82) gives $\Sigma Px = Pl \times 0{\cdot}158+$.

To find where P must be applied so as to produce a maximum strain at the fixed end, we make equation (82) a maximum.

For this we find $n = 0{\cdot}422+$,

which in (82) gives $\Sigma Px = Pl \times 0{\cdot}181+$,

and in (83) gives $\Sigma Px = Pl \times 0\ 131+$.

To find where P must be applied so that the strain at the point of application will equal that at the fixed end we make (82) equal (83) and find

$$n = \begin{cases} 1{\cdot} \\ 2{\cdot}732 \\ -0{\cdot}732 \end{cases}$$

none of which values except the first answer the conditions of the problem. But as the strains given by these equations may have contrary signs, and as we only seek numerical equality, we will place (82) equal (83) with its sign changed, and we shall find

$$n = \begin{cases} 1{\cdot} \\ 0{\cdot}5858 \\ 3{\cdot}4141 \end{cases}$$

the first two values of which are admissible.

The second value in (82) or (83) gives

$$\Sigma Px = Pl \times 0{\cdot}171+$$

To find when P must be applied so that the curve at the point of application shall be horizontal, we make $\frac{dy}{dx} = 0$ and $x = nl$

in (77) or (80) and we find

$$n = 0{\cdot}5858+$$

which is the same value as that given above for the point for equal strain.

For $n = 0{\cdot}5858$, tang $i = 0$,

" $n > 0{\cdot}5858$, tang i is negative,

" $n < 0{\cdot}5858$, tang i is positive.

To find the corresponding deflection make $x = nl$, and $n = 0{\cdot}5858$ in (78); this gives

$$f = 0{\cdot}0098\frac{Pl^3}{EI}$$

But this may not give the maximum deflection. To find where P must be applied so as to produce a maximum deflection, we must first know on which side of the point of application the maximum will be. Suppose that it is between the fixed end and the point of application.

Then we find where the curve is horizontal when P is applied anywhere, by making $\frac{dy}{dx} = 0$ in (77); which gives

$$x = \frac{2\,(3-n)\,n^2-4n}{(3-n)\,n^2-2};$$

and the corresponding deflection is found by substituting this value in (78). Then we find that value of n which will make this a maximum. If the maximum deflection be on the other part of the beam, we proceed in a similar way with equations (80) and (81). I have not made the reductions.

To find the point of contra flexure, make $\frac{d^2y}{dx^2}=0$ in (76)which gives

$$x = \frac{3ln^2-n^3l-2nl}{3n^2-n^3-2}$$

For instance, if $n = \frac{1}{2}$, $x = \frac{3}{11}l$

It is worthy of note that at this point the moment of strain is naught; hence there is neither elongation nor compression of the fibres, but there is a transverse shearing which may be found by equation (63). Its value at all points between the fixed end and the point of application of P is

$$S\delta = \Sigma P = P - V$$

Substitute the value of V, from equation (76), and we readily find that

if $n = \frac{1}{2}$, $S\delta = P - \frac{5}{16}P = \frac{11}{16}P = 0{\cdot}6875P$

if $n = 0{\cdot}5858$, $S\delta = 0{\cdot}5845P$

if $n = 0$, $S\delta = P$.

The *law of resistance* which we have just considered has been applied in the discussion of Tubular Girders.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

On the Constitution of Sea-water at Different Depths and in Different Latitudes. By Prof. FORCHHAMMER, of Copenhagen.

From the London Chemical News, No. 263.

The number of elements hitherto found in sea-water the author stated to be thirty-one—viz: oxygen, hydrogen, nitrogen in ammonia, carbon in carbonic acid, chlorine, bromine, iodine in fuci, fluorine in combination with calcium, sulphur as sulphuric acid, phosphorus as phosphoric acid, silicium as silica, boron as boracic acid (discovered by the author in sea-water and in sea-weeds), silver in the *Pocillopora alcicornis*, copper very frequently both in animals and plants of the sea, lead very frequently in marine organisms, zinc principally in sea plants, cobal and nickel in sea plants, iron, manganese, aluminium, magnesium, calcium, strontium, and barium, the latter two as sulphates in

fucoid plants, sodium, potassium. These twenty-seven elements the author himself had ascertained to occur in sea-water. The presence of the next four elements—viz: lithium, cæsium, rubidum and arsenic—has been shown by other chemists. Of these elements only a few occur in such quantity that their determination has any notable influence on the quantitative analysis of sea-water—viz: chlorine, sulphuric acid, magnesia, lime, potash, and soda. The others, as far as their existence has been determined in the sea-water itself, are found in the residue which remains after evaporation to dryness and re-dissolution of the salts in water. The author next stated that, in the water of the ocean far from the shores, the principal ingredients always occur very nearly in the same proportions. If we assume chlorine = 100, the mean proportion of the other leading constituents is as follows:—

	Mean proportion.	Maximum.	Minimum.
Sulphuric acid, . .	11·89	12·09	11·65
Lime, . . .	2·96	3·16	2·87
Magnesia, . .	11·07	11·28	10·95
All salts, . .	181·1	181·4	180.6

These proportions apply only to specimens obtained at a long distance from shores or in the open ocean. In the interior of the Baltic, for instance, the proportion of chlorine to sulphuric acid is as 100 to 14·97; to lime as 100 to 7·48; and the proportion of chlorine to all salts as 100 to 223·0. This constant proportion of the different constituents in the ocean depends evidently not upon any chemical combination and affinity between the different substances, but upon the enormous quantity of salts in the whole ocean, which renders imperceptible any difference that might otherwise arise from the different proportion in which salts are carried into the sea by rivers. It depends besides on the uniform action of the numberless organic beings inhabiting the ocean, which abstract sulphuric acid, lime, potash, and magnesia from the water, and render them insoluble. The mean quantity of solid matter in the water of the ocean generally the author found to be 34·304 per 1000.

Relative to this paper the President in his annual address made the following observations:—This communication forms a valuable contribution to a great subject—the history of the sea. It contains a full and compendious inquiry into the constituents of the water of the ocean, divided into seventeen geographical regions, each of which is studied separately from samples taken both at the surface and at various depths. An accurate view is thus gained for the first time of the sea as a whole, and conclusions of great generality are obtained. The minute analytical processes followed in several hundred analyses were so conducted as, in the opinion of competent judges, to inspire entire confidence. They confirm the presence in sea-water of the twenty-five elements already reported by other chemists, and add two others, boron and aluminium, to the number. But it is chiefly by the application of the data thus obtained to the elucidation of various geographical problems of great and general interest that we are led to recognise the full importance of this memoir. I may permit myself to notice one or two of the most remarkable of the conclusions established by it. In

the Atlantic the saline ingredients in the sea-water (the samples being taken at proper distances from the land) decrease with increasing depth. This is found to hold good even to extreme depths. The existence of a polar current in the depths of the Atlantic is hence inferred, since it is a well-established fact that the equatorial seas are richer, and the polar seas poorer, in saline ingredients. The large amount of saline contents found by analysis of the water of the well-known current flowing from north-west to south-west, between Iceland and the east coast of Greenland, shows it to be, not as heretofore supposed, a polar current, but one of equatorial origin. The inference is, that it is a returning branch of the great Gulf-stream, which we have recently had reason to recognise as extending to the shores of Nova Zembla and to the north coasts of Spitzbergen, carrying to Nova Zembla the floats of the Norwegian fishermen, and to Spitzbergen the same floats, mingled with wood from Siberia. May it not be possible that the "iceless sea, teeming with animal life," described by the adventurous American explorer, Dr. Kane, as viewed from the promontory which formed the northern limit of his research, is, as he himself surmised, but an extension of the same equatorial stream which produces correspondingly abnormal effects at Spitzbergen, as well as at every other point to which its course has been traced? When physical researches shall be resumed within the circle which surrounds the Pole, this, perhaps, will be one of the earliest problems to receive solution—a solution rendered now so simple by the method of inquiry which Professor Forchhammer has made known to us.

Pro. Roy. Soc. Nov. 24, 1864.

Japan Matches.

From the London Chemical News, No. 264.

Dr. Hofman, having been reminded by the Secretary that at the last meeting he had promised them an experiment, replied that after the important matter discussed that evening, and at the late hour, it was with reluctance that he addressed the Society. He had, however, heard that the Olympian gods, after diligently attending to their celestial business, were occasionally pleased to come down upon earth and to indulge in the pursuits and amusements of ordinary mortals. These Olympic traditions had been happily revived in the Chemical Society, by Mr. Septimus Piesse. The descent of the gods used to take place in a cloud of lightning. They would remember that at the conclusion of the last meeting, Mr. Septimus Piesse had furnished them with a cloud; although late in the evening, he begged permission to supply the lightning. Dr. Hofmann then exhibited some *small paper matches* which were lately given to him, and said to have been brought home from Japan. He lighted several of these matches, which burned with a small, scarcely luminous flame, a red-hot ball of glowing saline matter accumulating as the combustion proceeded. When about one-half of the match had been consumed, the glowing head began to send forth a succession of splendid sparks. The phenomenon gradually assumed the character of a brilliant scintillation very similar to that observed in burning a steel spring in oxygen, only much more delicate,

the individual sparks branching out in beautiful dendritic ramifications. His first idea, Mr. Hofmann continued, had been to look for a finely divided metal in the mixture. But when examined in his laboratory, it had been found quite free from metallic constituents, and to contain carbon, sulphur and nitre, only. These constituents were present in the following proportions:—Carbon, 17·32; sulphur, 29·14; nitre, 53·64. Each match contained about 40 milligrammes of the mixture, which was folded up in fine paper. There had been no difficulty in imitating these matches. A mixture of carbon 1 (powdered wood charcoal), sulphur 1½, and nitre 3¼, produced the phenomenon in even a more striking manner. The choice of the paper was not without importance. Ordinary English tissue paper might be used. The finest matches were, however, obtained by employing genuine Japanese paper, a supply of which had been recently forwarded to him by Baron Magnus, of Berlin. In conclusion, Dr. Hofmann said that, owing to its delicacy, the phenomenon was better adapted for individual observation than for exhibition before a large audience. He had, therefore, prepared a number of these matches, which were distributed among the members of the Society.

Science in the Witness-Box.

From the London Chemical News, 265.

A writer in *Blackwood's Magazine* makes the following remarks on the examination of scientific witnesses in courts of law:—"The grandest achievement of all is a poisoning case—something that is to be two-thirds emotional and one-third scientific—where the interest vacillates between the most powerful passions and the pangs of arsenic; and the listener is alternately carried from the domestic hearth to the laboratory and back again. Now, when one is aware that the 'learned Serjeant' knows as much about chemistry as a washerwoman does of the 'wave theory,' the display of impromptu learning he makes is positively astounding. Armed with an hour's reading of Beck and Orfila, the great man comes down to court to puzzle, bewilder, and very often to confute men of real ability and acquirement; to hold them up to the world as hopelessly ignorant of all that they had devoted their lives to master; and in some cases to exhibit the very science they profess as a mass of crude disjointed facts, from which no inference could be drawn, or a safe conclusion derived. . . . A pitiable specimen is that poor man of science, pilliored up in the witness-box, and pelted by the flippant ignorance of his examiner! What a contrast between the different caution of the true knowledge, and the bold assurance, the chuckling confidence, the vain-glorious self-satisfaction, and mock triumphant delight of his questioner! Mark the practised leer, the Old Bailey grin with which he comments on something that science still regards uncertain or obscure, and hear him declare to the jury that, in the present state of medical knowledge, there is not a man in court might not be indicted for having handed the salt or the mustard to his neighbor!"

For the Journal of the Franklin Institute.

A Uniform System of Screw Threads. By Robert Briggs.

The subject of a uniform system of screw threads has recently been before the Franklin Institute, having been introduced by a paper from Mr. William Sellers, of this City, read April 21st, 1864, and having been investigated by a Committee appointed by the Institute, who have reported their conclusions at the meeting of December 15th. This report favors the adoption as the basis of uniformity, of the changes in the pitches and shapes of the threads proposed in the paper of Mr. Sellers, and does not enter so fully as might be wished into the various considerations which should influence the final decision, but is simply a confirmatory acknowledgment of the reasonings of that paper. The writer having some years since given a careful examination of the subject, would now lay before the public some of his results, not as adding much to the information of those already conversant of the points at issue, but as so fully collecting most of the considerations involved, that an undue importance shall not be given to some of them, and the partial examination lead to erroneous deductions.

On commencing the consideration of the subject, we find that custom and the practice of mechanics for many years, has established a certain number of threads per inch corresponding to each diameter of bolt or nut, and a particular form for the thread itself is so generally adopted as to bear evidence of the thoughtful design and evident purpose of many thousands of constructors and users.

The numbers of threads per inch and their form in habitual use, were examined and collated by Mr. Joseph Whitworth in 1841, and formed the subject of an excellent paper read by him at the Institution of Civil Engineers in London.

To most of the conclusions of that paper, founded as it was entirely on practice and divested of any hypothesis beyond that practice, the whole engineering world has acquiesced, and within the limits for which bolts and nuts are used as fastenings and in which the threads on the bolts have been cut by dies, and the threads within the nuts cut by taps, which limits can be stated as between one-fourth inch to two inches diameter, the number of threads designated by him, has, with one or two exceptions, been used by all subsequent makers of screws.

The most marked exception from Mr. Whitworth's table of numbers has been in the case of the $\frac{1}{2}$-inch and $\frac{5}{8}$-inch bolt threads, where it has been found that the designated numbers give so coarse a pitch to the screws, as to materially weaken the bolts by the reduction of their diameters at the roots of the threads.

The practice of different workshops has been to make the half-inch bolt, in place of the twelve threads the table calls for; thirteen, thirteen and one-half, or fourteen threads to the inch. The two latter numbers proceeding directly from three and nine, or from seven, being got readily from the ordinary change gear of screw cutting lathes, and are therefore preferable to thirteen. Similarly $\frac{5}{8}$-inch bolts are made frequently with twelve threads in place of the tabular number eleven. It

will be shown further on in this discussion, that these changes have not only a practical but a theoretical basis, founded on those comparisons of proportions which can be instituted by means of graphic scales or formulas, with great propriety, before assuming as established relative parts of similar details of machinery. It is very possible that the present excellence of our screw cutting apparatus, by producing more perfect threads, would allow finer pitches than the practice of former days, even taking times so recent as 1841, were the strength of bolts under the roots of the threads and the power to be gained in the application of the screw alone considered.

But it is requisite not only to possess the ability to screw the nut up in the first instance, when the threads are, or can be clean and well oiled, but also to be able to unscrew it after the threads are clogged with dirt or rust or the oil has hardened.

The ability to perform the latter operation without risk of twisting off the bolt depends directly on the angle of inclination of the threads, or in other words, on the pitch. The frequency with which bolts are twisted off, especially the larger ones, in the effort to unscrew their nuts is an evidence that to meet this condition alone, even coarser pitches than those in general use would be desirable.

When we reflect on the quantities of bolts and nuts in existence and their general conformities, it becomes apparent that nothing but a radical improvement will justify disturbing the balance of advantages which our present dimensions have by practice attained.

Mr. Whitworth's deduction of the form to be given to the triangular threads, has however, not met with the same universal approval and compliance. On the contrary the angle of 60° appears to be that in most general use in England and to be exclusively used in the United States, in the place of the angle of 55° which the paper recommends. This angle of 60° presents one great advantage of acquirement, independent to the exact shape of the single point or chaser which cut- the steel from the tap (or hob which originates the chasers) in permits ting the finishing of the form of the thread, or the backing off of the tap by ordinary three cornered files.* The section of the angle of a sharp three square file is exactly that which the thread requires, as the corner, although called sharp, is really a little rounded and gives the desirable hollow at the root of the thread. We therefore see that the general practice of mechanics every where is towards a uniformity in the use of screw threads, and that very little adjustment of differences, as to number of threads to be used, or the form of thread to be adopted is necessary, and it is probable that the mutual agreement of a few leading mechanical institutions with the co-operation of some of the larger screw bolt making establishments, would meet general approval, and final entire following. It is to be noticed, however, that

* It cannot with strictness be said to be impossible, it is only difficult, to back off with a file, a tap or tool for cutting either the Whitworth or Sellers form of thread. By using a three-cornered file the shape can be cut away at the back and the face of the cutting edge in front left the original outline, but the labor required would be much greater and the skill of the workman taxed to produce a satisfactory *job* to use the workshop expression.

there is much discrepancy in the exact diameters when the nominal diameters are the same. That is, there are no standard dimensions, so that bolts and nuts of different makers and nominally of the same diameters, and having the same form of thread shall certainly interchange upon placing any nut upon any bolt.

Most of the nominal sizes in use by mechanics, whether expressed by feet or inches, or by numbers, refer to arbitrary gauges, and neither correspond to nor in any simple terms can be compared with our units of measure.

Thus gas and steam pipes of wrought iron have nominal diameters which correspond neither to the actual internal or external ones.

The diameter of wrought iron turned shafts is called that which it has been found convenient to have the merchantable round iron from which they are turned, and the thickness of sheet iron or the diameter of wires have no simple numerical relation between the numbers of the gauges and the actual dimension in inches or aliquot parts.

Similarly there is needed a set of arbitrary fixed gauges in the sizes of male and female threads so that the workman should be independent of the necessity of comparison by callipers and by rules. It not being important within a few thousandth of an inch what dimension those gauges have, only that they shall be called by their nearest diameters in sixteenths of an inch, and that they shall ensure an actual correspondance of size for all bolts and nuts of each nominal dimension.

In this regard also we are confident that standard gauges for bolts and nuts would meet approval and following.

Having thus stated the prominent facts which are open to investigation, we will now proceed to a more theoretical as well as practical examination of them.

It is evident that our attention can only be called to those bolts which are to be generally used for fastenings, for confining parts of fixed machinery or pipe flanges together, as the requirements of service for particular uses do not admit of the complete generalization of all screws.

Thus very coarse threads, which shall be either square or truncate (angular with the top and bottom corners removed) or angular in sec tion, are demanded for valve screws, lathe screws for screw cutting or for the spindles or chucks, and generally for all running or frequently used screws; while very fine threads, very well fitted, are suitable wherever the screws are subject to jars as about hammers and on locomotive engine work. In pipes, the thickness of the material gives a limit to the coarseness of the threads and screws to run in wood, lag screws, or wood screws generally, where the strength of the two materials vary essentially call for a dissimilarity of form between the internal and external threads. In these instances any attempt to introduce a further uniformity of screw threads, than what would be comprised in a uniformity in each particular group of conditions, would be to ignore the laws of constructive mechanism.

We therefore propose to consider only the usual fastening bolts as

within the scope of the present inquiry into the propriety of establishing a uniformity, but would therefore not the less endeavor to impress on all special manufacturers, as of lathes, of locomotives, of steam and gas pipes, of gas fixtures, of instruments, of wood screws, the necessity and desirability of agreeing amongst themselves as to the definite and uniform dimensions of their screws.*

We also propose to consider these bolts for fastenings only within the limits of one-fourth to two inches diameter. (The latter bolt requiring three men on a forty-eight inch lever, each man exerting a pull of 100 lbs to pull the nut home to its maximum safe strain.)

Above two inches diameter, bolts are usually chased, and the nuts cut in a lathe and the uniformity with other bolts is made to depend so much upon the workman who fits each nut to its bolt that it is impracticable to ask, if not impossible to ensure it.†

* NOTE.—The manufacturers of wrought iron steam and gas pipes, have already established and agreed to the sizes and proportions of their pipes and threads, which are shown in the accompanying table from Morris, Tasker & Co.'s List.

TABLE *of Standard Dimensions of Wrought Iron Welded Tube.*

Nominal Diameter.	Actual Outside Diameter.	Thickness.	Actual Inside Diameter.	Internal Circumference.	External Circumference.	Length of Pipe per sq. foot of inside surface.	Length of Pipe per sq. foot of outside surface.	Internal Area.	External Area.	Length of Pipe containing one cubic foot.	Weight per foot of length.	No. of threads per inch of screw.
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Feet.	Feet.	Ins.	Ins.	Feet.	lbs.	
¼	0·405	0·068	0·270	0·848	1·272	14·15	9·44	0·0572	0·129	2500.	0·243	27
⅜	0·54	0·088	0·364	1·144	1·696	10·50	7·075	0·1041	0·229	1385.	0·422	18
½	0·675	0·091	0·494	1·552	2·121	7·67	5·657	0·1916	0·358	751·5	0.561	18
⅝	0·84	0·109	0·623	1·957	2·652	6·13	4·302	0·3048	0·554	472·4	0·845	14
¾	1·05	0·113	0·824	2·589	3·299	4·635	3·637	0·5333	0·866	270·	1·126	14
1	1·315	0·134	1·048	3·292	4·134	3·679	2·903	0·8627	1·357	166·9	1·670	11½
1¼	1·66	0·140	1·380	4·335	5·215	2·768	2·301	1·496	2·164	96·25	2·258	11½
1½	1·9	0·145	1·611	5·061	5·969	2·371	2·01	2·038	2·835	70·65	2·694	11½
2	2·375	0·154	2·067	6·494	7·461	1·848	1·611	3·355	4·430	42·36	3·667	11½
2½	2·875	0·204	2·468	7·754	9·032	1·547	1·328	4·783	6·491	30·11	5·773	8
3	3·5	0·217	3·067	9·636	10·996	1·245	1·091	7·388	9·621	19·49	7·547	8
3½	4·0	0·226	3·548	11·146	12·566	1·077	0·955	9·887	12·566	14·56	9·055	8
4	4·5	0·237	4·026	12·648	14·137	0·949	0·849	12·730	15·904	11·31	10·728	8
4½	5·	0·247	4·508	14·153	15·708	0·848	0·765	15·939	19·635	9·03	12·492	8
5	5·563	0·259	5·045	15·849	17·475	0·757	0·629	19·990	24·299	7·20	14·564	8
6	6·625	0·280	6·065	19·054	20·813	0·63	0.577	28·889	34·471	4·98	18·767	8
7	7·625	0·301	7·023	22·063	23·954	0·544	0·505	38·737	45·663	3·72	23·410	8
8	8·625	0·322	7·982	25·076	27·096	0·478	0·444	50·039	58·426	2·88	28·348	8
9	9·688	0·344	9·001	28·277	30·433	0·425	0·394	63·633	73·715	2·26	34·077	8
10	10·75	0·366	10·019	31·475	33·772	0·381	0·355	78·838	90·762	1·80	40·641	8

Taper of threads, 1 to 32 on each side.

In estimating the effective steam heating or boiler surface of tubes, the surface in contact with the air or gases of combustion (whether internal or external to the tubes) is to be taken.

For heating liquids by steam or transferring heat from one liquid or one gas to another, the mean of the internal and external surfaces is to be taken.

An enlarged section of a pipe thread showing the form and the taper of the screw is given Fig. 3, Plate III.

† NOTE.—In this country there has been in use the past few years some machines for cutting the screws upon bolts, based upon the scroll screw plate of Mr. Whitworth, so that the cutting dies can be removed after the bolt is threaded without backing out the bolt, a process which endangers the cutting edges of the dies either from friction or from the liability of a piece of swarf jamming on the tooth.

Besides, there are certainly no reasons founded on former established habit which will justify the use of any thread on a bolt so large as two-and-one-fourth inches diameter or above, which does not answer the exact condition of the special requirement of use for the bolt.

The mechanic who is about to fix upon the proportions of anything similar to other things in use, refers either directly or by memory to a comparison of dimensions with what he, or others may have before done. Thus he would reason, if ten threads to an inch are needed or are used for three-fourth inch bolts, then some less number would be suited to an inch and-a-half bolt, and as he would consider the quantity of iron to be removed as well as the diameters of the respective bolts, he would decide the number of threads on the latter should not be in inverse ratio of the diameters, but rather less, and he might fix upon six threads for the proper number.

Proceeding further for other sizes he would infer that seven-eighths inch bolts should be coarser threaded than three-fourths inch, one inch bolts than seven-eighths, &c., and he would intuitively construct a table which should embrace all the sizes between three-fourths and one-and-a-half inch bolts, and perhaps above and below those dimensions, the whole being based upon, and having its correctness dependent on the assumption as regards the three-fourths inch bolt first, and the derived assumption as regards the one-and-a-half inch bolt last. The workman would thus by a species of mechanical perception, have established a series of proportional dimensions and when the minds

These cutter dies are usually made on the principle patented in this country about 1848, by P. W. Gates, and then introduced by him.

(Mr. Gates' patent seems to have been anticipated by one to A. Lamont in 1830, but it is certain his method was not brought into use until he advocated it in person.)

The cutters are placed in the scroll plate with the planes of their cutting faces radial to the centre of the plate and are tapped or chased out parallel a little larger than the screw which is to be cut. The entering side of the plate is then coned out so as to obliterate the first thread and remove the points of three or four more.

Upon setting in the cutters to the size of the screw, it will be found that the backs of the teeth are relieved, and if the proper allowance for this relief has been made in the enlarged size of the original hole, they will (when sharpened to the right cutting form on the face) act precisely like well made lathe tools.

Machines with die plates as described have been successfully introduced into many workshops, and especially have come into use in the Railroad shops for cutting the larger bolts required in bridge construction where lathe cut screws have hitherto been used. Although the whole number of bolts reckoned by numbers wanted for these purposes is very small, yet it is cheaper to fit up a set of dies and taps to thread them, than to cut them in the lathe, beside admitting the cutting of long bolts without welding. The question has, therefore, arisen as to what should be the best form of thread and the pitch of the threads for bolts of this description, say from 2¼ inches to 3½ inches diameter.

In this case the question is divested of the average practice of mechanics in both regards and should be decided on its own merits.

To quote from Mr. Sellers: "The necessity of guarding the edge of the thread from accidental injury becomes more and more apparent as the size of the bolt is increased. Considering the whole case on the basis of our own paper, as well as on its merits, we think that bolts for bridge construction, might by agreement of Railway Engineers, as a special case, have a form approximating to Mr. Whitworth, of 60° sides with rounded top and hollow at bottom of thread.

of many have been brought to the consideration of the same point in the same way, these proportional dimensions will be found expressible in some algebraical form of the general case.

Thus supposing P = the pitch of the thread, or the distance from the point of one thread to the point of another.

d = the outside or nominal diameter of the bolt,

and N = the number of threads,

we have at once $N = \frac{1}{P}$ or the reciprocal of P and we find the following formula to express as nearly as the fractional character of the exact results can be expected to, the proposed and proper numbers of threads to an inch to be used for screw bolts.

First, Mr. Whitworth's table is very nearly expressed by

$$P = 0{\cdot}1075\,d - 0{\cdot}0075\,d^2 + 0{\cdot}024 \text{ inch.}$$

Second, Mr. Sellers proposes

$$P = 0{\cdot}24\,\sqrt{d + 0{\cdot}625} - 0{\cdot}175 \text{ inch.}^*$$

Third, the writer uses within limits

$$P = 0{\cdot}096\,d + 0{\cdot}026.$$

The Table on page 117, shows the results of these three formulas.

The formula which so closely expresses the values of Mr. Whitworth's tables cannot be extended beyond his upper limit. At 7⅛ ins. diameter the curve of the values of P reaches its maximum, and the values then decrease with the increase of the diameters.

The formula of Mr. Sellers, gives a curve whose final form would be $0{\cdot}24\sqrt{d}$ where d is so large that the constants can be neglected and consequently is not open to the palpable defect of Mr. Whitworth's formula, but the pitches becoming proportionally finer for the large sizes the question of ease of unscrewing is to be investigated. It is difficult to discover on what grounds the second power, or the square root of d should enter into these equations at all.

The formula of the writer alone has any value (beyond describing arbitrary and undesired curves) as its simplicity admits of its application to other purposes, especially in calculating the general case of the useful effect or strength of the system of screw bolts as modes of fastening or in sustaining loads. This formula could be extended to all practical dimensions and although the pitches for the larger bolts above 3 inches appear out of proportion when compared with Mr. Whitworth's tables, it can be demonstrated Mr. Whitworth's are dis-

* Note.—Mr. Sellers gives

Δ = diameter of screws,
x = pitch of screws,
a = constant 2·909
c = divisor 16·64
d = number of sixteenths plus ten in Δ,

$$x = \frac{\sqrt{d} - a}{c} = \frac{\sqrt{16\,\Delta + 10} - 2{\cdot}909}{16{\cdot}64}$$

$$\therefore\ x = 0{\cdot}24\,\sqrt{\Delta + 0{\cdot}625} - 0{\cdot}175$$

proportionately fine when the nut is to be removed from the rusted bolt.

It is to be noticed that all the formula agree in showing the discrepancy in the pitch assumed by Mr. Whitworth for the half-inch bolt, and that admitting his other tabular values to have the correct basis of average practice, this one was a general departure from the common law.

Tabular results of the three formulas.

Diameters of Bolt.	Mr. Whitworth.			Mr. Sellers.		Writer.	
	Exact Numbers.	Nearest Aliquot.	Table.	Exact Numbers.	Nearest Aliquot.	Exact Numbers.	Nearest Aliquot.
$\frac{1}{4}$	19·80	20	20	20.	20	20.	20
$\frac{5}{16}$	17·57	18	18	17·85	18	17·84	18
$\frac{3}{8}$	15·79	16	16	15·38	16	16·13	16
$\frac{7}{16}$	14·37	14	14	13·90	14	14·7	15
$\frac{1}{2}$	13·17	13	12	12·50	13	13·5	14
$\frac{9}{16}$	12·18	12		11·49	12	12·5	12
$\frac{5}{8}$	11·32	11	11	10·75	11	11·63	12
$\frac{3}{4}$	9·95	10	10	9·36	10	10·2	10
$\frac{7}{8}$	8·90	9	9	8·40	9	9·09	9
1	8·06	8	8	7·63	8	8·2	8
$1\frac{1}{8}$	7·39	7	7	6·99	7	7·47	7
$1\frac{1}{4}$	6·82	7	7	6·49	7	6·85	7
$1\frac{3}{8}$	6·35	6	6	6·10	6	6·34	6
$1\frac{1}{2}$	5·94	6	6	5·71	6	5·88	6
$1\frac{5}{8}$	5·59	6	5	5·40	$5\frac{1}{2}$	5·49	$5\frac{1}{2}$
$1\frac{3}{4}$	5·29	5	5	5·13	5	5·16	5
$1\frac{7}{8}$	5·02	5	$4\frac{1}{2}$	4·90	5	4·84	5
2	4·78	$4\frac{1}{2}$	$4\frac{1}{2}$	4·67	$4\frac{1}{2}$	4·59	$4\frac{1}{2}$
$2\frac{1}{4}$	4·39	$4\frac{1}{2}$	4	4·31	$4\frac{1}{2}$	4·13	4
$2\frac{1}{2}$	4·06	4	4	4·00	4	3·76	$3\frac{3}{4}$
$2\frac{3}{4}$	3·73	4	$3\frac{1}{2}$	3 76	4	3·45	$3\frac{1}{2}$
3	3·58	$3\frac{1}{2}$	$3\frac{1}{2}$	3·54	$3\frac{1}{2}$	3·18	$3\frac{1}{4}$
$3\frac{1}{4}$	3·39	$3\frac{1}{2}$	$3\frac{1}{4}$	3·35	$3\frac{1}{2}$	2·86	3
$3\frac{1}{2}$	3·24	$3\frac{1}{4}$	$3\frac{1}{4}$	3·19	$3\frac{1}{4}$	2·77	$2\frac{3}{4}$
$3\frac{3}{4}$	3·11	3	3	3·04	3		
4	2·99	3	3	2·92	3		
$4\frac{1}{4}$	2·90	$2\frac{7}{8}$	$2\frac{7}{8}$	2·81	$2\frac{7}{8}$		
$4\frac{1}{2}$	2·81	$2\frac{7}{8}$	$2\frac{7}{8}$	2·71	$2\frac{3}{4}$		
$4\frac{3}{4}$	2·73	$2\frac{3}{4}$	$2\frac{3}{4}$	2·61	$2\frac{5}{8}$		
5	2·68	$2\frac{3}{4}$	$2\frac{3}{4}$	2·53	$2\frac{1}{2}$		
$5\frac{1}{4}$	2·62	$2\frac{5}{8}$	$2\frac{5}{8}$	2·45	$2\frac{1}{2}$		
$5\frac{1}{2}$	2·57	$2\frac{5}{8}$	$2\frac{5}{8}$	2·38	$2\frac{3}{8}$		
$5\frac{3}{4}$	2·54	$2\frac{1}{2}$	$2\frac{1}{2}$	2·31	$2\frac{3}{8}$		
6	2·51	$2\frac{1}{2}$	$2\frac{1}{2}$	2·25	$2\frac{1}{4}$		

Fig. 1, Plate III, shows a graphic delineation of the curves and lines expressed by the formulas.

A bolt is subject to two strains, tension or the strain in direction of the length of the bolt, occasioned by the load it carries or the force it expends in holding the parts it confines together: and torsion, which is the force in the plane of rotation tangential to the cylindrical body of the bolt and is composed of two distinct applications of power, first, that which proceeds from the component of the load on the inclined screw surface, which is either positive or negative as the screw is employed to raise or lower the load; and secondly, that which comes from the frictional resistance of the moving screw surfaces under the loads imposed upon them.

The capacity of the bolt to resist tensional strain, is of course, dependent on the area of the section at the root of the teeth, and the shallower the teeth, either from using fine pitches or by having a great angle, at the tops and bottoms or by rounding or truncating the points, the larger that area.

Ordinary wrought iron, such as is generally used in bolts can be stated to be reliable for maximum load under 20,000 lbs per square inch, and the absolute tensile strength of any bolt may be safely estimated on that basis.

It is well to remark at this place that the rounding of the root of the thread adds to the tensile strength of the bolt should it be strained to its utmost, and come to its safe working strain of one-third the ultimate one.

Thus a piece of iron of the following shape, say, $\frac{1}{2}$-inch in diameter at the smallest part, and 1 inch in diameter at the central enlargement will, from the conditions of elasticity of solid bodies, be impaired in tensile or torsive strength by the abrupt enlargement, one-fifth to one-fourth of that which a plain bar of one-half inch diameter would possess. The torsional strain which is exerted on the bolt in screwing up, when the component of force expended in producing tension is positive, equals the tensional strain (that is, the bolt is as likely to twist off as to tear asunder) when the value of the co-efficient of friction has certain definite amounts.

We will not attempt to enter into this calculation, but will only give results, trusting that the evident probability of these results may suffice in this place and taking the following special cases:

Nominal diameters, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 2, 3, ins.
Value of frictional co-efficient when torsion equals tension, 0·32, 0·33$\frac{1}{2}$, 0·34, 0·35, 0·35$\frac{1}{2}$, 0·36,

showing a slight increase of torsional strength in these cases for the larger bolts. And generally that in screwing up bolts there is no danger of twisting them off, unless, the frictional resistance exceeds one-third the insistant load.

Similar calculations have given for unscrewing where the component of force expended in relieving the tension is negative, a similar table of results, only that the differences of values for frictional co-efficient, which would twist off the bolt are reversed, and the larger resistance must be taken for the smaller bolt. And the general result

in this last case is that, about 38 per cent. must be taken for the average value of the frictional co-efficient to twist off the bolt.

The frictional resistance encountered in turning a nut can hardly be called that of motion, as each successful wrench-hold finds the surfaces of contact in a state of rest, but in screwing up the nut, the condition of these surfaces is much more favorable than in unscrewing after a lapse of time under load, and this value of 38 per cent. is often reached on rusted, and not oiled screws. The larger bolts not only have greater values to their frictional co-efficients from the less angle made by the thread with the plane of rotation relatively with the smaller bolts; but are generally more closely fitted by their nuts, so that their nuts are not so readily started by a few blows when fixed by rust. Coarser pitches give at once the possibility of looser fitting nuts and better angle of thread-line for relief.

The next point for discussion is the form of the threads. If bolts were made of uniformly sound iron (not to say of the highest tensile strength), and if nuts were so well fitted that the bearing should always extend over the whole surface of the threads in place of being a contact on but some portion of that surface at the tips, (which occurs when the threads have not the same angular form or when the diameter of the bolt is smaller than is proper for the calibre of the nut); such a thing as a stripped screw (with the usually adopted height of nut) would be unknown, whether the threads were triangular or Whitworth formed, or truncated and independent entirely on the fineness of the threads employed.

But in practice, both unsound iron and badly fitted nuts, not only occur but are to be taken into account in the view we now institute.

The merchantable round iron from which bolts are made is often shelly and loose on the external skin, caused either by the piling of the fagot from which it is rolled, by the closing down of fins formed in the process of rolling, or by more serious defects in the iron itself; and the punched nut is liable to have its fibre destroyed by the operation of cold punching, with badly made or dull punches and dies, (the parallel requirement of the hole compelling the use of punches the same size with the die being unsuited, however sharp, to cutting the iron out) so that it is a normal condition of the usual bolts and nuts of the workshop, and the market, to be made of poor material. Beside all this, the requirements of ease of fixing, demands a shaking fit, that no little dirt or rust or indentation will prevent the use of the bolt in the trench, on the boiler, over the furnace, or at the work-bench.

And this extreme latitude of imperfections is not to be taken as interfering with the proper accuracy of the best workshop practice. Supposing all the above mentioned allowances are made, they will not prevent the use of the best iron and the forged or hot pressed nut, neither will they preclude the bolt which shall be made the full size of the standard being accurately and properly fitted by the nut which shall be tapped out to the smallest dimension which the standard bolt will admit. After these remarks it is easy to see that the finally adopted form must be that which balances many conditions against others

and is not a matter of calculation, but for deliberation. Thus the finer the pitch, (the form of threads being assumed,) the stronger the bolt, but with the fine pitches we are deprived of the requisite looseness of fitting and the threads being cut in the external laminæ of iron are likely to be imperfect and weak. If, after what we have before said, we are prepared to coincide with universal practice and assume the pitches, as given by our formula, then the less depth the threads have, the stronger are the bolts, but with the shallow threads the bearing surfaces are reduced, or if angular, cause excessive frictional resistances. Then there is the question of convenience in making tools for cutting bolts and nuts, and the question of ease with which such tools will operate in threading, and the question of durability of the tools in service. We will not pursue this abstract view further. Making machinery *a priori* is a palpable absurdity. In Mechanics the performance always precedes the reason for it, and sometimes taxes the reasoner beyond his ability. It has been assumed that the form of the teeth of bolt threads under discussion shall have the outline of angle of 60°, more or less rounded at the point and hollowed at the root. The angular form gives the junction at the root of the tooth with the body of the bolt or nut the largest section possible, while the action of the load upon the inclined surface affords a capacity to resist stripping, proportionate to the angle of inclination. (Strictly speaking, proportional to the tangent of the angle of inclination.)

In wooden screws and nuts, the angle of 90° for the sides of the thread has been found to present that resistance at which they rarely strip, although the fibre of the wood presents the most favorable direction for splitting.

With a slight round or truncation at the points, they are made very loose to allow the wood to swell or shrink and in the case of hand or bench screws of the cabinet or pattern maker are very durable in service.

Screws about a trip hammer when tapped into cast iron require fine pitches to keep them from jarring out, and the same section of thread as wood screws have to obtain the same advantages over the more friable material. For mathematical instruments and for screwing in thin plates, screws sometimes have the angle of 45° especially when steel is the substance of both bolt and nut.*

The deep tooth given by the angle of 60°, permits much looseness of fit, allows imperfections of thread, either from the wear of tools or from defects of iron, and presents a large bearing surface for the load on the bolt; of course all these are at the expense of the strength of the bolt, but for example, if a three-fourths inch bolt is not strong enough to perform a certain duty it is better to use a seven-eighths bolt, and thus preserve the advantages enumerated.

In the cases of tie rods for roof or bridge construction this condition of enlargement of rods to obtain requisite strength under the roots of the threads does not exist at all. All sound or economical engineering demands that the ends of such rods shall be upset at welding

*Any person wishing to study this subject should, before concluding, examine Holtzapffel's Mechanical Manipulation, Vol. II.

heat and swedged to such diameter as shall allow the root of the thread when cut to be larger than the body of the rod elsewhere, both to secure an excess of tensile strength and also to gain something to resist the cross strain which generally affects such rods from an unfair bearing of the nut on its seat, besides the reduction of weight and cost of the entire rod. Consequently the pitch and form of threads for such screws should be exactly what is wanted, and are to be determined independent from those adapted to ordinary purposes.

There is no form of cutting edge so easily produced or maintained in shape as that of a simple triangle and the form of tooth we have described, is too well known to all mechanics to need here in a paper addressed to them any further statement or argument in favor of its advantages.

Recurring to the alternative forms proposed, Mr. Whitworth's form is not attainable by any ready or convenient process of the workman.

By means of master taps, hobs and chasers which are all perishable as standards of form, at great expense of gauges as samples, it might be feasible to introduce and perpetuate it.

The head of the best reputed workshop in Great Britain, himself one of the most esteemed writers on mechanical subjects, has been twenty-three years endeavoring to introduce this decription of thread with such success as only to bear evidence of the general reluctance to change, even for the attainment of uniformity. Mr. Sellers' form has some advantages over that of Mr. Whitworth, first, that a gauge which he describes places it in the power of any workman to originate the exact shape of each size; secondly, that when the taps and dies are new and unworn, considerable additional bearing surface on the threads is gained by the substitution of corners for the rounded ends at the points and roots of the threads; and thirdly, by some considerable additional strength which the reduction of depth of threads may give to the bolts themselves. The latter advantage being in common to both the proposed forms, as contrasted with the usual V form.

Considering these points in order, first, the gauge proposed by Mr. Sellers is almost as valuable for originating Mr. Whitworth's thread as his own, as it gives a definite length for the extremities of the threads hardly attainable otherwise. It is certainly a very ingenious and satisfactory method of accomplishing its purpose. Secondly, the gain of bearing surface: this would disappear rapidly with the wearing away of the corners of the teeth, so that the final appearance, which might result, if after use, some person should collate the average form of thread made by taps and dies originally with sharp cornered truncations would hardly differ in any discernible respect from Mr. Whitworth's result.

The deterioration of the V form of 60° is towards a correspondence with Mr. Whitworth's result, and a completely worn out tooth, has a shape approximating to two semicircles with a tangential contact of the curves, the ends of the tooth being rounded off, and the internal corner hollowed out until what there is left of the side is nearly vertical

to the bolt. Thirdly, the gain of strength from the shallowness of the threads equal, this point has been before met in the general discussion, by pointing out the advisability of enlarging the bolt rather than of reducing the thread surface.

As a conclusion therefore we take the form of thread as shown in an enlarged outline, see fig. 2, Plate III, as appearing to have so extensive sanction in use, that much more weighty reasons should be found before we would willingly recommend any change.

Were either the alternative shapes, that endeavored to be introduced by Mr. Whitworth, or that proposed by Mr. Sellers, in general use the question could be entertained as to the propriety of revising the form in favor of that we now have, and notwithstanding the confusion such a change would entail we think many would consent to the effort. As it is on the principle of holding fast to that which is good, we cordially recommend a uniformity of gauges and pitches, together with our usual form of V thread, as follows: The form has, when new, the depth of 0·8, the pitch in place of 0·866 which would be the dimension were the corners made absolutely sharp. This depth is that which the best workshop practice for well fitted bolts has adopted, but the custom of those who make bolts as an article of sale, has been to make a further allowance on the corners, so that the depth of common threads is about 0·75 the pitch of the threads. The commonly made bolt will always run in the well made nut, but the well made bolt will only run in the usual nut, when that nut is made slightly larger than a perfect fit. The real enlargement needed, however, is but the three thousandth part of an inch of diameter in a three-fourth inch bolt, and is within the limits of looseness required for merchantable bolts. So that the well made screws will operate in all cases in practice with good common ones, if the original gauges correspond, except as regard the extreme angular depths.

Proceeding to the examination of the dimensions of the nuts. The form of the nut is to be determined by the convenience of turning, and the general advantages of four or six sides can be conceded without argument. Nuts with five, eight or ten sides, spanner nuts of various arrangements of pins or polls are required for special purposes, but four or six sides alone give convenience of griping or proper surfaces to grip upon.

The height of the nut is to be established by the following considerations. First, what height is required for wear, and to meet the frictional resistance on the surface of the threads? Second, by the convenient wrench-hold for turning. Third, by what is needed for strength of threads to resist stripping. The load on the surface of the threads of a well-fitted bolt or nut of the section before proposed, is from 25 to 20 per cent. of the tensional strain on the section of bolt, below the root of the threads, and it varies but little for whatever value of friction co-efficient we adopt whether screwing or unscrewing. That this load is excessive, we show by special example.

Suppose the height to be assumed at equal the diameter of the bolt, and take a three-fourths bolt and nut for instance. A workman exert-

ing a force of sixty pounds on a twelve inch long lever, (or wrench,) will raise fifty-five hundred pounds, (at least) and the insistant load on the thread surface becomes about eleven hundred pounds, the tension on the iron of the bolt will then be 20,000 lbs per square inch, and the insistant load on the thread surfaces over four thousand lbs per square inch.

It is one of the most striking corroborations of the laws of frictional resistances that subject to constant use under loads to this amount, (as our statement of the length of lever and force applied to it will make evident to any mechanic,) nuts are turned by forces proportionate to the loads upon them.

Nothing but the universality of the proportion stated, would warrant the deduction that it is sufficient.

Founded on practice, we take the height of nut equal the diameter of the bolt as regards frictional requirement, but we consider it the least practical height admissible.*

The wrench-hold also is taken as sufficient on the same basis of habit that being the only guide for the settlement of this requirement.

As for the strength needed to resist stripping, making allowance for loss of root connexion with the body of the bolt occasioned by the hollow at the bottom, it still remains that the whole height of nut (of sound iron) demanded to resist detrusion, is but one-fourth the outside diameter of the bolt and if the fit is very imperfect and loose, so that each thread has the nature of a beam supported at one end and loaded one-half way out, one-half the diameter becomes abundant.

All the conditions are consequently fulfilled if the first is answered. And we conclude H should equal d.

The diameter for the nuts measured across the inscribed circle is fixed first, at that which will resist the oblique strain on the threads tending to split the nut, making all allowances for imperfections of forgings and the strain of tapping; and second, by the area of surface of the under side of the nut, which carries the load; and third, by that which gives the facets of the nut sufficient size for wrench hold.

It will suffice here to say that calculations have been made to show the value of the strain tending to split the nut, that it varies between one-half to two inch nuts, from one-tenth to one-seventh the tensional strain on the section below the root of the thread of bolts, and that the consideration of the two last points only is needed; these considerations giving sufficient strength to resist tapping strains which is not susceptible of estimation.

We will assume as in the case of the height of the nut that the inscribed diameter of the nut shall be expressed by a formula as below.

$$D = 1\tfrac{1}{2}\,d + \tfrac{1}{8} = 1{\cdot}5 + d\ 0{\cdot}125$$

and our calculations give the following results:†

*This great weight on the surface of the threads justifies the practice of making nuts much higher when they are to be frequently turned.

†The bearing of the nut is taken to be the area of the inscribed diameter of the nut, minus the area of the hole in the flange, or surface on which it rests, which hole with some allowance for clearance, is assumed to have the diameter of

$$= 1{\cdot}03\ d + 0{\cdot}03.$$

let K = tensional strain on iron of bolt per square inch.

K_{III} = load on the under surface of nut " "

These for the following sizes of bolts,

diameters $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 2,

$\frac{K_{III}}{K}$, 0·17, 0·31, 0·39, 0·43, 0·47, 0·50

That is, for a two inch bolt the load on the surface of the nut is one-half the tension on the bolt so that when the bolt is tightened to its utmost safe strain of 20,000 lbs per square inch, the load on the nut surface will be 10·000 lbs per square inch. Bolts certainly do work and work well under these insistant loads on the surfaces of friction, but nothing but use would justify carrying the laws of friction to any such extreme points, and the figures evidently show the necessity of finished nut surfaces and of washers on the larger sizes.

The dimensions of the facets of the nuts are found to be ample when the sizes of nuts are those which the assumed formula gives.

We conclude on $D = 1{\cdot}5d + 0{\cdot}125$

when D equals inscribed diameter of nut whether square or hexagon.

The dimension of the heads are governed by the same considerations which we have stated for the nuts, except that the requirement for height is not dependent on frictional resistance on the surface of the threads and the demand for convenient wrench-hold has fixed on

$H, = 0{\cdot}8d$ as ample

when H, = height of head.

The diameters are more conveniently the same, as that of the nuts, so that the same wrenches fit, if occasion demands.

Proceeding on our assumption that the depth of the threads shall equal 0·8P, we obtain for the diameter of the root of the thread of any bolt $= d_2 = d - 2\,(0{\cdot}8P)$, for best workshop bolts, or,

$d_2 = d - 1\,(07{\cdot}5\ P)$, for good merchantable bolts, this would be the diameter of the hole in a nut to be tapped out if it were not found necessary to allow for the upsetting of the iron towards the points of the threads which results in cutting away the opposite sides at the same time. If it were attempted to run a tap into a hole the same diameter as the body of the tap, the iron would clog upon the tool and present a great resistance to driving it, while the thread would almost invariably strip.

In cast iron the thread would certainly crumble away, and in wrought iron it would only be preserved by the stretching of the thread, as a burr on the side opposite that in which the tap is entered. The amount of the allowance necessary is dependent on the dulness of the tap, or the care and skill with which the teeth have been *backed off* so as to cut like lathe tools.

Making the proper allowances for these considerations we have for the diameter of hole in untapped nuts $d_h = d - 2\,(0{\cdot}7P) + 0{\cdot}01$ for ordinary use, and $d_h = d - 2\,(0{\cdot}75P) + 0{\cdot}005$ for very well made and sharp taps and best fitted nuts.

Journal Franklin Institute.

Fig. V

Fig. VI. Form of trun
for Valve a

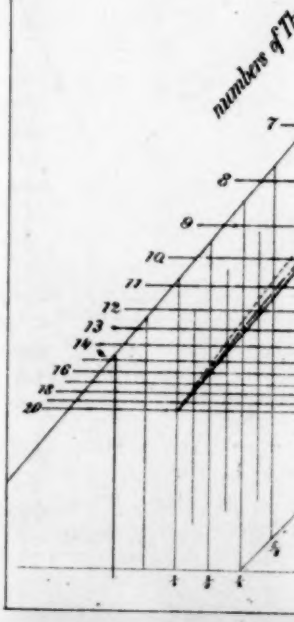


Fig. V Section of Wrought Iron Pipe Thread

rm of truncated Thread suited
r Valve and Lathe screws.

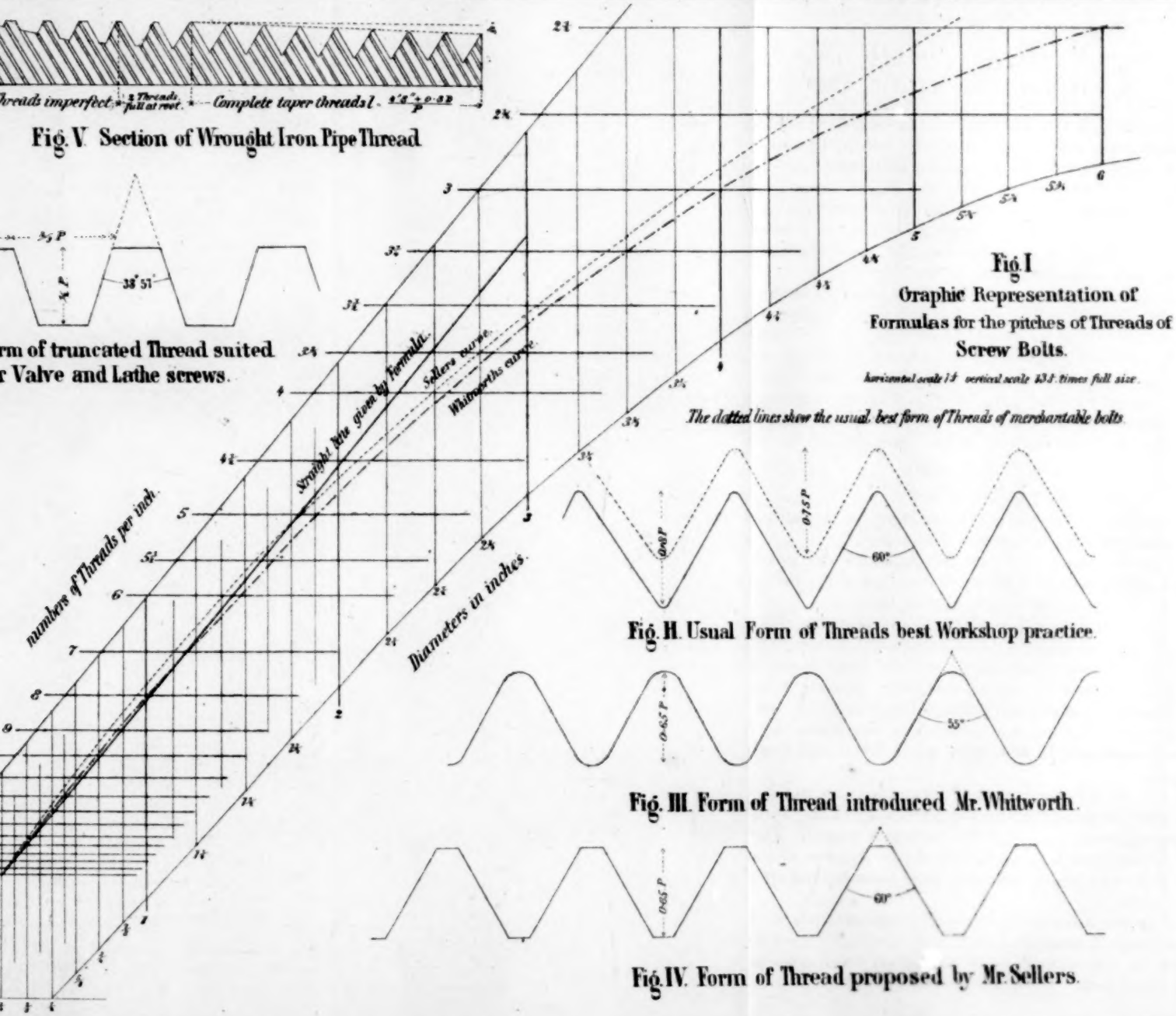


Fig. I
Graphic Representation of
Formulas for the pitches of Threads of
Screw Bolts.
horizontal scale 1/3 vertical scale 4/3 times full size.

The dotted lines show the usual best form of Threads of merchantable bolts

Fig. II. Usual Form of Threads best Workshop practice.

Fig. III. Form of Thread introduced Mr. Whitworth.

Fig. IV. Form of Thread proposed by Mr. Sellers.

"We recapitulate the formulas relative to the system of screw threads.

1st. The number of threads per inch $N = \frac{1}{P} = \frac{1}{0{\cdot}096d + 0{\cdot}026}$

2d. The depth of the threads for best finished screws $= T = 0{\cdot}8P°$.
" " " " merchantable " $= T = 0{\cdot}75P°$.

3d. The inscribed diameter of nut or head whether square or six sided, $D_n = 15d + 0{\cdot}125$.

4th. The height of the nut, $H = d$

5th. The height of the head, $H = 0{\cdot}8d$

6th. The diameter of the hole in the nuts before tapping out $= d_h$

The following table gives the results of the first of these formulas.

The following table gives the results of our discussion:

Diameter of Bolt.	Number of Threads.	Diameter of Nut.	Height of Nut.	Diameter of holes in nuts, allowing for upsetting of threads.	Height of Heads.
$\frac{1}{4}$	20	$\frac{1}{2}$	$\frac{1}{4}$	0·190	0·2
$\frac{5}{16}$	18	$\frac{9}{16}$	$\frac{5}{16}$	0·255	0·25
$\frac{3}{8}$	16	$1\frac{1}{16}$	$\frac{3}{8}$	0·297	0·30
$\frac{7}{16}$	15	$\frac{3}{4}$	$\frac{7}{16}$	0·355	0·35
$\frac{1}{2}$	14	$\frac{7}{8}$	$\frac{1}{2}$	0·410	0·4
$\frac{9}{16}$	12	$1\frac{1}{16}$	$\frac{9}{16}$	0·452	0·45
$\frac{5}{8}$	12	$1\frac{1}{16}$	$\frac{5}{8}$	0·518	0·5
$\frac{3}{4}$	10	$1\frac{1}{4}$	$\frac{3}{4}$	0·62	0·6
$\frac{7}{8}$	9	$1\frac{7}{16}$	$\frac{7}{8}$	0·729	0·7
1	8	$1\frac{5}{8}$	1	0·84	0·8
$1\frac{1}{8}$	7	$1\frac{3}{4}$	$1\frac{1}{8}$	0·935	0·9
$1\frac{1}{4}$	7	2	$1\frac{1}{4}$	1·060	1·0
$1\frac{3}{8}$	6	$2\frac{3}{16}$	$1\frac{3}{8}$	1·152	1·1
$1\frac{1}{2}$	6	$2\frac{3}{8}$	$1\frac{1}{2}$	1·277	1·2
$1\frac{5}{8}$	6	$2\frac{9}{16}$	$1\frac{5}{8}$	1·402	1·3
$1\frac{3}{4}$	5	$2\frac{3}{4}$	$1\frac{3}{4}$	1·48	1·4
$1\frac{7}{8}$	5	$2\frac{15}{16}$	$1\frac{7}{8}$	1·605	1·5
2	$4\frac{1}{2}$	$3\frac{1}{8}$	2	1·7	1·6

Lime Abroad and at Home.

From the London Builder, No. 1140.

My experience being somewhat at variance with the statements put forward under this and a like heading in the last two numbers of the *Builder*, it may, perhaps, be worth giving. The mode described of making mortar in Southern Italy has been practised in this country, time, immemorial. A pit is dug in the ground, may-be 30 ins. deep,

large enough to contain perhaps a one or two horse-load of lime. Water is put into the pit, the lime is shoveled in gradually, while at the same time it is stirred to and fro with a mortar fork, and so on till the whole is dissolved to the consistency of thick cream; the stones of course settle at the bottom, and when the lime subsides the water is run off. In a short time a firm bed of putty is ready to make mortar of, then, or at any time within six months, if the lime-pit be protected from rain and sun. Of course a hard film or protective coating forms itself on the surface; under this the lime remains fresh and mellow to almost an indefinite length of time. Of mortar made with lime so prepared, I can testify from twenty years experience to its hard-setting and durable qualities. It has never occurred to me to test exactly the qualities of this as compared with any other mortar prepared from fresh-slaked lime; but I may observe that the practice of making mortar from lime-putty, and in the rough-and-ready way above described, seems to be dictated by necessity rather than choice. It prevails chiefly in the country where, from the great distance it has sometimes to be carted, it would be impracticable, for ordinary building purposes, to have fresh-slaked lime on every occasion. W. M.

An Account of Apparatus and Processes for the Chemical and Photometrical Testing of Illuminating Gas. By Prof. W. B. Rogers.

From the London Athenæum, Oct., 1864.

The instruments and methods described in this communication are those adopted in the gas inspection lately organized by Prof. Rogers, for the State of Massachusetts; comprising the measurement as well as testing of gas. Connected with the former of these objects, an account was given of the adjustments of the standing measure for gauging gasholders,—of a universal clamp for meter-connexions,—and of an appendage combining a delicate thermometer and pressure gauge for the inlet and outlet of the meter, and by which the rate of delivery is accurately adjusted. For chemical testing, the eudiometer, consisting of a graduating tube, with cylindrical enlargement, is permanently enclosed in a wider tube full of water, which maintains the temperature nearly uniform. The mouth of the graduated tube is furnished with a hollow ground stopper, for holding the several liquid absorbents used in the successive experiments. With this apparatus it is easy to determine the percentage of carbonic acid, of illuminating hydrocarbons, of oxygen, and of carbonic oxide; after which the hydrogen and light carburetted hydrogen are ascertained by explosion, by means of an instrument consisting mainly of two glass tubes, united below by a long loop of rubber-tube, being a modification of Frankland's apparatus. For determining the sulphur, an improved arrangement is used, in which the stream of water supplying the Liebig's condenser is made to convey a stream of air, mingled with ammonia, into the condensing tube some inches above the flame of the burning gas. To secure a larger and more constant unit of illumination than the candle commonly used, a lamp burning kerasine, with a flat wick, is employed, in

which, by means of a bridge of platinum wire, the flame may be maintained of constant size, and giving a light equal to about seven candles. This is supported on a balance of peculiar construction, giving the consumption during the experiment. Prof. Rogers had found that even the small amount of carbonic acid which in some gas-works is allowed to remain in the gas produces a sensible reduction of the light. This effect varying with the strength of the illuminating gas, was found to range from 3 to nearly 5 per cent. of the illuminating power for each per cent. of the impurity: 58 per cent. of carbonic acid, although it did not prevent combustion, made the flame so dim as to be without effect on the photometer.

On Boring Rocks.

From the London Mechanics' Magazine, December, 1864.

SIR:—The enormous outlay which attends the opening and working of mines in districts where the strata are, as in Cornwall, of an exceedingly hard nature, is due mainly to the slow progress which can be made in sinking shafts, or driving levels or headings through such refractory rocks. Thus £60 per fathom is not an unusual price for sinking a shaft in hard Cornish stone; and even at this immense cost the progress made is very small. In solid limestone rock a shaft 9 feet in diameter can be sunk for £7 per fathom, and at the rate of ten fathoms per month; but a shaft in hard capal or roskear stone costs £60 per fathom, and perhaps not one fathom per month can be sunk.

In each case, the labor is mainly accomplished by boring holes in the rock, and firing them with charges of powder, the explosion of which bursts, and breaks up the rock.

Now in limestone these holes can be rapidly bored, because limestone is considerably softer than good hardened steel, and therefore the steel borer keeps its edge a long time, and cuts the rock keenly and quickly. But capal or roskear stone is nearly and often quite as hard as the best hardened cast steel; hence the edge of the borer is soon worn or beaten up, and in place of cutting the stone keenly, it merely bruises it away by degrees, making slow progress through it, and to enable even this to be done, the edge of the borer bit has to be made very thick and obtuse, and in a form the least calculated to penetrate rapidly. In boring a hole 8 inches in hard veinstone, upwards of 200 borer bits have had to be re-set by the smith, and the cost of each re-setting or tempering is fairly stated at about threepence for each bit, taking labor, loss of time, &c., &c., into consideration. Now, if a steel can be produced which, when hardened, will be as much harder than capal or roskear stone as the best hardened steel at present made is harder than limestone, then by the aid of this steel shafts may be sunk and levels driven in the hardest ground as rapidly and as economically as can at present be effected into ordinary limestone rock.

Such a steel can be produced, and I invite the attention of mining

engineers, contractors, mine owners, and shareholders in mines to this all-important subject. They need only test the steel according to my directions to convince themselves that what I have advanced can be borne out in practice. When used for boring ordinary rocks, this steel is all but imperishable in its edge. Two hundred feet have been bored with a single borer in limestone rock without the bit requiring to be fresh dressed and tempered.

Apart from any interest of my own as an inventor, this matter is one of the deepest national importance; and the adoption of the steel in question in the Cornish mines would enable the miner's interest there to set foreign competition at defiance, and numbers of mines now barely paying cost would at once spring up into dividend mines, whilst a multitude of other mines now abandoned from the depression of the prices of copper and tin would immediately be brought into active operation.

R. MUSHET.

Cheltenham, Dec. 26, 1864.

Trial of a New Machine for getting Coal.

From the London Mechanics' Magazine, December, 1864.

On Wednesday last a coal cutting machine, on an entirely new principle, the invention of Messrs. Lock and Warrington, colliery owners, Kippax, and Messrs. Carrett and Marshall, engineers, Leeds, was tried at the Kippax Colliery, near Leeds, in the presence of a number of colliery owners and mining engineers, including Mr. Embleton, Mr. Morton, Mr. Pope, Mr. Rayner, Mr. Parker, Mr. Pickersgill, and other gentlemen. The trial in every respect was perfectly successful, and every gentleman present expressed his satisfaction at the manner the machine performed its work. The coal-cutting machines which have been tried recently in other districts have been worked by compressed air, and on the principle of the pick motion. This machine is, however, worked by water pressure, at 150 lbs to an inch, conveyed in 1½ inch wrought iron pipes, from a small engine fixed near the bottom of the pit. The trial was made in the Allerton seam of coal, which is five feet six inches thick, but contains a layer of dirt three inches thick at the height of 20 inches from the floor, which separates the best and second seams of coal. The machine was mounted on four wheels, and traverse on the corf tramways. The "holing" or "baring," which is the hardest and most laborious part of the collier's work, was done remarkably well, in one even straight line, and to a uniform depth, at once passing over. The cutters were fixed in a slotting bar, worked with a steady longitudinal reciprocating motion at a slight angle, which ripped out the whole of the partition of dirt to a depth of three feet three inches. The apparatus being entirely *self-acting in all its operations*, it propelled itself forward, secured itself dead fast between the floor and roof, whilst the cutters were in operation, and again released itself with the return stroke. The machine is strong, and not at all complicated, and is likely to work with durability. It is beautifully arranged in its various movements, and works with such precision and exactness that any one might almost fancy it was endowed with intelligence. One man is all that is

quired to attend to it, and he has nothing to do but to set it in motion and stop it when required. The machine worked on Wednesday two hours forty-nine minutes, and excavated the dirt out three inches thick and three feet three inches under for a length of twenty-two yards and two feet, and liberated from the solid bed of coal forty-four tons. The average cost of "baring" by hand labor at the same colliery is 8d. per ton; but the principal saving is in the economical working of the coal, without cutting such a large proportion into slack as is done by hand labor. The pressure of water can be increased to any required extent and its quantity needs only to be enough to fill the circuit of the pipes, the same incompressible fluid thus being used over and over again to convey the power any required distance from the source of power to the coal seam to be operated upon. The miners have named this new labor saver the "iron-man," and from his self-acting and industrious powers, it is probable he will never become tired. Messrs. Lock and Warrington are so well satisfied with the advantages of getting coal by machinery that we understand they are making more machines in order to take all their coal worked by them.—*Leeds Mercury*, Nov. 21, 1864.

On a New Formula for Calculating the Initial Pressure of Steam.

By Mr. R. A. PEACOCK.

From the London Athenæum, Oct., 1864.

Some years ago the author had occasion to attempt to calculate the probable pressure of steam at the highest known temperatures, and found, amongst other things, that between the pressures of 25 lbs per square inch and 300 lbs to the square inch, the latter being the highest pressure to which trustworthy experiments had been carried, the law of increase was approximately: That the temperature of high-pressure steam of, say, 25 lbs to the square inch and upwards, increases as the $4\frac{1}{2}$ root of the pressure; and that, conversely, the pressure of the steam of, say, 25 lbs to the square inch and upwards, increases as the $4\frac{1}{2}$ power of the temperature. At lower pressures than about 25 lbs per square inch, a different law prevails. As it is necessary to verify the new formula by comparison with some well known formulas and experiments, the author has attempted to do so in a very voluminous table, and graphically in a very carefully executed diagram. What is to be gathered from these is, that the new formula agrees with Dr. Fairbairn's experiments, from about 40 lbs to 60 lbs and very nearly with Regnault's, between 220 lbs and 336 lbs.

Experiments on the use of Petroleum as a Fuel for Propelling Steam Machinery.

From the London Mechanics' Magazine, December, 1864.

An elementary course of experiments was commenced last week in the factory department of Woolwich dockyard, with a view of testing the capacity of petroleum to supersede coal and other fuel on shipboard, and also in propelling steam machinery in the factories. The

engineers, contractors, mine owners, and shareholders in mines to this all-important subject. They need only test the steel according to my directions to convince themselves that what I have advanced can be borne out in practice. When used for boring ordinary rocks, this steel is all but imperishable in its edge. Two hundred feet have been bored with a single borer in limestone rock without the bit requiring to be fresh dressed and tempered.

Apart from any interest of my own as an inventor, this matter is one of the deepest national importance; and the adoption of the steel in question in the Cornish mines would enable the miner's interest there to set foreign competition at defiance, and numbers of mines now barely paying cost would at once spring up into dividend mines, whilst a multitude of other mines now abandoned from the depression of the prices of copper and tin would immediately be brought into active operation.

R. MUSHET.

Cheltenham, Dec. 26, 1864.

Trial of a New Machine for getting Coal.

From the London Mechanics' Magazine, December, 1864.

On Wednesday last a coal cutting machine, on an entirely new principle, the invention of Messrs. Lock and Warrington, colliery owners, Kippax, and Messrs. Carrett and Marshall, engineers, Leeds, was tried at the Kippax Colliery, near Leeds, in the presence of a number of colliery owners and mining engineers, including Mr. Embleton, Mr. Morton, Mr. Pope, Mr. Rayner, Mr. Parker, Mr. Pickersgill, and other gentlemen. The trial in every respect was perfectly successful, and every gentleman present expressed his satisfaction at the manner the machine performed its work. The coal-cutting machines which have been tried recently in other districts have been worked by compressed air, and on the principle of the pick motion. This machine is, however, worked by water pressure, at 150 lbs to an inch, conveyed in 1½ inch wrought iron pipes, from a small engine fixed near the bottom of the pit. The trial was made in the Allerton seam of coal, which is five feet six inches thick, but contains a layer of dirt three inches thick at the height of 20 inches from the floor, which separates the best and second seams of coal. The machine was mounted on four wheels, and traverse on the corf tramways. The "holing" or "baring," which is the hardest and most laborious part of the collier's work, was done remarkably well, in one even straight line, and to a uniform depth, at once passing over. The cutters were fixed in a slotting bar, worked with a steady longitudinal reciprocating motion at a slight angle, which ripped out the whole of the partition of dirt to a depth of three feet three inches. The apparatus being entirely *self-acting in all its operations*, it propelled itself forward, secured itself dead fast between the floor and roof, whilst the cutters were in operation, and again released itself with the return stroke. The machine is strong, and not at all complicated, and is likely to work with durability. It is beautifully arranged in its various movements, and works with such precision and exactness that any one might almost fancy it was endowed with intelligence. One man is all that is

required to attend to it, and he has nothing to do but to set it in motion and stop it when required. The machine worked on Wednesday two hours forty-nine minutes, and excavated the dirt out three inches thick and three feet three inches under for a length of twenty-two yards and two feet, and liberated from the solid bed of coal forty-four tons. The average cost of "baring" by hand labor at the same colliery is 8d. per ton; but the principal saving is in the economical working of the coal, without cutting such a large proportion into slack as is done by hand labor. The pressure of water can be increased to any required extent and its quantity needs only to be enough to fill the circuit of the pipes, the same incompressible fluid thus being used over and over again to convey the power any required distance from the source of power to the coal seam to be operated upon. The miners have named this new labor saver the "iron-man," and from his self-acting and industrious powers, it is probable he will never become tired. Messrs. Lock and Warrington are so well satisfied with the advantages of getting coal by machinery that we understand they are making more machines in order to take all their coal worked by them.—*Leeds Mercury*, Nov. 21, 1864.

On a New Formula for Calculating the Initial Pressure of Steam.

By Mr. R. A. PEACOCK.

From the London Athenæum, Oct., 1864.

Some years ago the author had occasion to attempt to calculate the probable pressure of steam at the highest known temperatures, and found, amongst other things, that between the pressures of 25 lbs per square inch and 300 lbs to the square inch, the latter being the highest pressure to which trustworthy experiments had been carried, the law of increase was approximately: That the temperature of high-pressure steam of, say, 25 lbs to the square inch and upwards, increases as the $4\frac{1}{2}$ root of the pressure; and that, conversely, the pressure of the steam of, say, 25 lbs to the square inch and upwards, increases as the $4\frac{1}{2}$ power of the temperature. At lower pressures than about 25 lbs per square inch, a different law prevails. As it is necessary to verify the new formula by comparison with some well known formulas and experiments, the author has attempted to do so in a very voluminous table, and graphically in a very carefully executed diagram. What is to be gathered from these is, that the new formula agrees with Dr. Fairbairn's experiments, from about 40 lbs to 60 lbs and very nearly with Regnault's, between 220 lbs and 336 lbs.

Experiments on the use of Petroleum as a Fuel for Propelling Steam Machinery.

From the London Mechanics' Magazine, December, 1864.

An elementary course of experiments was commenced last week in the factory department of Woolwich dockyard, with a view of testing the capacity of petroleum to supersede coal and other fuel on shipboard, and also in propelling steam machinery in the factories. The

method adopted is the patented invention of Mr. C. J. Richardson, an engineer residing at Kensington. The plan under trial is simply to burn the petroleum through a porous material, which is placed in an iron chamber, dipped into a water vessel also of iron. The oil admitted into the chamber soddens the porous material, and rises by a sort of capillary attraction. The surface then catches fire and burns rapidly, as long as the oil is supplied. The effect of the flame is so great that with the small apparatus, which is only two feet superficial area and affixed to a boiler, the oil on Saturday was utilized so as to be equal for steam purposes to five tons of coals. A third advantage is obtained by the employment of the petroleum—namely, that no stokers are needed, and the boilers can be supplied with several fires one above another. The small grate used in the experiments was placed under a boiler of 17-horse power, and in two hours it raised the steam to 10 lbs pressure. The only objection seems to be the fear of explosive qualities, but these Mr. Richardson states he is prepared to guard against effectually.

Substitutes for Cranes and Hodmen in Paris.

From the Journal of the Society of Arts, No. 630.

The *Builder* states, that "some of the contractors re-building the demolished houses, and running up quickly new mansions, have hit upon an ingenious way of raising materials to the top of the scaffold. As the head of water at the Vilette is enough to command any of the houses in Paris, they have simply a pipe turned on from the main up to the top of the intended structure, and by that means can fill a bucket or large tub, which in descending draws up a plateau on which the materials are placed. The water, being turned into mortar, and otherwise made use of afterwards below, is not lost. Some of the materials are also hoisted by Lenoir's machine (by gas); there is one at work at the Rond Pont de Corcelles, close to the Avenue de Ternes. It seems to be, by timing a weight ascending a certain height, about 2½-horse power. The absence of a boiler in these engines is a strong argument in favor of employing them where steady slight power is required. At all events, if they are not endowed with the abundant force of a steam engine, yet in towns and confined streets, where only a moderate source of power is required to act in a small compass, noiselessly and without nuisance, we have seen that the required mechanical effect can be accomplished without risk of explosion, and consequent damage and loss of life, either to owners or their neighbors. That is something at all events."

Use of Petroleum as Steam Fuel in place of Coal. By B. H. Paul.

From the London Chemical News, No. 263.

Some months ago considerable interest was excited by the announcement that very remarkable results had been obtained in America by the application of petroleum as fuel for the boilers of steam vessels,

and so much importance was attached to the subject, that a Commission was appointed by the Government of the Northern States to inquire into this application of petroleum.

The report published by the Commission, as the result of their labors, was calculated rather to excite curiosity than to afford satisfactory information, and they have not, so far as I am aware, made public any further data which would afford a means of arriving at an opinion on the subject.

The proposal to use petroleum as steam fuel in ships became, almost of course, a subject of consideration in this country, and an idea prevailed that this invention might possibly supersede in importance all the recent improvements connected with the naval or mercantile marine. It was anticipated that not only naval warfare, but even navigation itself, might be completely revolutionized by this invention. It was reasonable enough that a project put forward with such pretension as was the case in respect to the use of petroleum as fuel for steam vessels, should be considered in a country where every improvement relating to steam navigation is of high importance; but it is surprising that no one should have disabused the public mind of the erroneous impressions produced by the statements as to the use of petroleum as fuel; for to any one conversant with the composition and characters of petroleum, as compared with coal, this proposed application of it was obviously absurd.

Lately little has been heard of this project until some days ago a notice appeared in the *Times*, under the head of "Naval and Military Intelligence," that experiments are being conducted at the Woolwich Dockyard, with the view of testing the capability of petroleum to supersede coal and other fuel on ship-board, &c. In this notice it was stated that the oil was so utilized "as to be equal for steam purposes to five tons of coal!" How much of the oil was equal to five tons of coal was not stated, but it may be fairly supposed that any one unacquainted with the subject would infer that one ton of oil was meant.

Now, what are really the facts of the case as to the comparative advantages of petroleum and coal as fuel?

In the first place, one of the chief alleged advantages of petroleum over coal, was that it would lie in a small compass and make less demand upon space and tonnage than coal does. Since with petroleum in the place of coal, two-thirds of the space now required for fuel in a steam vessel would be saved, steamships might keep at sea three times as long as at present. Then, coal depots would be unnecessary for steam packets on the longest lines of ocean navigation; and since no stokers would be needed in using petroleum, a whole army of employees might be dispensed with.

Now, the specific gravity of coal is from 1·24 or 1·44 to 1·6, while that of petroleum is from 0·800 to 0·850, consequently the weight of a cubic foot of these materials would be, respectively, about as follows:—

	lbs.	lbs.	lbs.
Coal, . .	77·4	90	100
Petroleum, .		50	53

But, since petroleum, being liquid, lies in a more compact manner than coal; in estimating the spaces occupied by these materials, allowance should be made for the interstices or empty spaces between the lumps of coal. Taking this as amounting to one-third of the whole bulk of a heap of coals—which is a liberal allowance—the contents of a cubic foot would be as follows:—

	lbs.	lbs.	lbs.
Coal, . .	52	60	70
Petroleum, .	50	53	—

So that the spaces occupied by equal weights of coal and petroleum would be about as 1 is to 1·2 or 1·4.

Then the relative heating power of equal weights of coal and petroleum would depend upon their respective chemical composition, which may be compared as follows for 100 parts:—

	Coal.	Petroleum.
Carbon, . .	83	85
Hydrogen, . .	5	15
Ash, &c., .		
	100	100

Accordingly, the relative heating power of equal weights of coal and of petroleum would be in the following ratio:—

	Coal.	Petroleum.
Calorific power, . .	1·02	1·50

And the spaces occupied by quantities of petroleum and of coal, having equal heating power, would be in the ratio of 1 to 1·16.

This difference in favor of petroleum is in itself too small to admit of any advantage being gained in regard of stowage, and it is more than doubtful whether there be any other advantageous difference between petroleum and coal for fuel.

It must also be considered how far the difference between the prices of petroleum and coal would have the effect of neutralizing the above or any other advantage to be gained by the use of petroleum as fuel. The price of petroleum varies from 15*l.* to 20*l.* per ton, while that of coal used for steam vessels is under 1*l.* per ton at any part of the British coast, and even at the coaling stations in the East it does not exceed 2*l.* 10s. to 3*l.* 10s. per ton.

These considerations alone appear to me to decide the question as to the practicability of using petroleum as steam fuel under any possible circumstances, for even in the case most favorable for the comparison of petroleum with coal, the cost of equal quantities of heat produced from these materials would be in the ratio of 15*l.* to 4*l.*

In addition to this, the highly inflammable nature of petroleum must be considered. Its storage on board a ship would require the use of air-tight vessels, and even then there might be considerable risk of the production of explosive mixtures of the petroleum vapor and air. But what would be the condition of a vessel of war provided with petroleum as fuel, if a shot penetrated the vessel containing the petroleum, and allowed it to escape in proximity to the boiler fires?

Taking all these circumstances into consideration, I think there cannot be any doubt as to the entire fallacy of supposing that petroleum can be substituted for coal as fuel; and though this conclusion is sufficiently evident from the data I have adopted as to price, &c., it must also be remembered that the tendency is rather to a rise in the price of this commodity than otherwise.

On the Chemical History and Application of Gun-cotton. By Prof. ABEL, F.R.S., Chemist to the War Department.

From the London Chemical News, No. 235.

Continued from page 44.

Many attempts have been made from time to time to diminish the rapidity of explosion of gun-cotton, but the only one which has been attended by any success is that which, in General von Lenk's hands, has led to the development of a system of mechanical arrangement of gun-cotton as ingenious and simple as it is effective. By manufacturing the cotton into yarn of different thickness and degrees of compactness or firmness of twist, *before* its conversion into gun-cotton, this material is at once obtained in forms which not only burn with great regularity and much less rapidity, when used in the original condition, than the loose gun-cotton wool, but which also when employed in the form of reels, wound more or less compactly, or, by being converted into plaits or hollow ropes, may be made to burn gradually in a manner similar to gunpowder, or to flash into flame instantaneously, exerting an explosive action which very far exceeds that of the latter. The modifications in the nature and degree of explosive force exerted by gun-cotton which are essential for its application to military and industrial purposes as a substitute for powder, are therefore arrived at by means of very simple variations in the mechanical condition of the material. Thus, to obtain the gradual action essential for the employment of gun-cotton in cannon, cartridges are made up of coarse yarn, which is wound firmly around a hollow cylinder of wood, the dimensions of which are regulated by the size of the gun-chamber and the weight of the charge used; the best result is obtained by so arranging the latter that the cartridge entirely fills the space allotted to the charge in the gun. Similarly, small-arm cartridges are made of cylindrical plaits of fine yarn or thread, which are fitted compactly in layers, one over the other, upon a small cylinder or spindle of wood. In both of these arrangements the combustion of the charge can proceed only from the exterior surfaces towards the interior of the cartridge. On the other hand, the charges for shells, in which the most rapid explosion is most effective, and the priming for quick matches which are intended for firing several charges simultaneously and almost immediately upon the application of flame, consist of cylindrical, hollow, and moderately compact plaits (similar to lamp-wicks), made of gun-cotton thread or very fine yarn. These plaits are produced in pieces of any length, and, when employed as quick-match, are compactly enclosed in cases of water-proof canvass or other similar mate-

rials. The charges to be used in mines, in which the most destructive effects are aimed at, consist of pieces of very firmly twisted rope, with a hollow case along the centre, the number of strands of which it is composed varying with the size of the charge to be used. For quarrying and blasting purposes suitable lengths of the rope are employed singly; for military operations (demolition of works, &c.), it is packed into moderately stout cases of sheet metal. In these hollow ropes and plaits of gun-cotton, the flame produced by the burning of that portion to which heat is applied, penetrates at once to the interior and into the interstices of the charge; and hence the entire mass of gun-cotton is converted into gas and vapor with almost instantaneous rapidity. A striking illustration of the very opposite effects which can be produced by very simple modifications in the mechanical arrangement of the gun-cotton is afforded by the following experiment: If two or three strands of gun-cotton yarn be very loosely twisted together and inserted into a tube of glass or other material, in which they fit so loosely as to be readily drawn backwards and forwards, upon applying heat to a projecting portion at one end of the tube, the gun-cotton thus arranged will explode with great violence, completely pulverizing the tube, if it be of glass, and the combustion will take place with such almost instantaneous rapidity that small portions of unburnt gun-cotton will actually be scattered by the explosion. But when two or more strands of the same gun-cotton yarn be tightly twisted, singly in the first instance, then made up into a firm cord solid throughout, and enclosed in a glass tube, or some other description of case, into which the cord fits very tightly, if a protruding end of the gun-cotton be inflamed, the cord will burn with moderate rapidity until the fire reaches the opening of the case, and then the combustion will pass over from the ordinary kind to a form which can only be described as smouldering; the lighted extremity of the gun-cotton simply glows within the case, while a steady jet of flame (furnished by the combustible gases evolved from the gun-cotton) continues to burn at the open extremity of the case until the contents of the latter are consumed. The gun-cotton not only burns extremely slowly under these conditions, but also with the greatest regularity; so that the rate of combustion of a given length of the enclosed cord may be accurately timed. The rapidity of combustion of gun-cotton arranged in this form may be regulated by the number of strands in a cord and the degree of their compactness; and it is by this new modification of General von Lenk's system of arranging gun-cotton that the lecturer has succeeded in applying this material to the production of slow-matches and time-fuses —uses for which it had not previously been found suitable.

Reference has just been made to inflammable gases evolved by gun-cotton while it undergoes a very slow combustion. The composition of gun-cotton renders it self-evident that under any circumstances the explosion of this substance must be accompanied by the production of a very considerable proportion of carbonic oxide. The large body of flame always observed when gun-cotton is ignited under ordinary circumstances, is principally due to the combustion of carbonic oxide, and

probably also of small quantities of carbo-hydrogen compounds, which, together with minute suspended particles of the mineral matter contained in the gun-cotton, give to the flame its brightness. If a tuft of gun-cotton be ignited in a capacious and somewhat deep vessel, the flame actually resulting from the burning of the tuft may be distinctly seen surrounded by a large body of flame, produced by the burning gases, which continues apparent for a very appreciable time after the disappearance of the flash of flame furnished by the explosion of the gun-cotton. If similar tufts be ignited in atmospheres of hydrogen, nitrogen, carbonic acid, coal gas, &c., the combustion of the gun-cotton is only accompanied by a very small and pale flame, of instantaneous duration. Similarly, if gun-cotton be ignited in a vessel which has been previously exhausted to any rate one-half the ordinary atmospheric pressure, the proportion of air, and therefore of oxygen, present when the gun-cotton is ignited, does not suffice to effect the combustion of any large proportion of the inflammable gases generated, and hence the explosion of the gun-cotton is attended only by a small pale flame. If, however, the vessel be filled with oxygen, and then exhausted to an equal or even a lower degree, it is filled with a flame of dazzling brightness directly the ignition of the gun-cotton is effected.

The one modification, just referred to, of the phenomena which attend the ignition of gun-cotton in a rarefied atmosphere is not the only result observed in experiments of this kind. Various curious effects may be obtained, their nature being determined by the degree of rarefaction of the atmosphere; the mechanical condition of the gun-cotton; its position with reference to the source of heat employed; and other variable elements in the experiments. A brief account of some of the principal of these phenomena may not be without interest.

In the experiment with a tuft of gun-cotton in rarefied air, spoken of just now, a perceptible interval is observed between the first application of heat (by passage of a voltaic current through a platinum wire enclosed in the tuft) and the first appearance of ignition of the gun-cotton; moreover, the pale flame, observed when the latter does burn, is of very perceptibly longer duration than that of the bright flash which attends the explosion of gun-cotton in air under ordinary conditions. If instead of using the gun-cotton in the form of a tuft, a short piece of the gun-cotton yarn be employed in the experiment, and laid on a support so that it rests upon the wire by which it is to be ignited, the pale flame of the burning gun-cotton will travel along towards the two extremities of the piece of yarn with a degree of slowness corresponding to the extent of rarefaction of the atmosphere. These results are in perfect accordance with the observation first made by Quartermaster Mitchell, afterwards fully examined into by Frankland, and recently amplified by Dufour, that the rate of burning of time-fuses is influenced by the altitude at which they are burned, or, in other words, by the degree of pressure of the atmosphere, the combustion being proportionately slow with every decrement of pressure of the air. When the platinum wire is first raised to a red heat in the centre of the tuft of gun-cotton, enclosed in a highly rarefied atmosphere, the products

resulting from the decomposition of that portion of the material which is in close contact with the wire, immediately distribute themselves through the rarefied space, conveying away and rendering latent by their expansion the heat furnished by the platinum-wire and that which results from the chemical change. The increase of pressure within the confined space, by the generation of the gases and vapors, on the one hand, and, on the other hand, the effect of the heated gases, which escape, upon the particle of gun-cotton through which they permeate, result, in the course of time, in the ignition of the mass; but, even then, the gun-cotton burns only slowly, because, in consequence of the rapidity with which the resulting gases and vapors escape and expand, much of the heat essential for the maintenance of the combustion is at once conveyed away. The latter result is strikingly exemplified by the experiment in which gun-cotton-yarn is substituted for the tuft of corded cotton; indeed, if the atmosphere be very highly rarefied (to 0·6 in inches of mercury), and a sufficient length of the gun-cotton-yarn (4 or 5 inches) be employed in the experiment, the burning of the material induced by the heated wire will proceed so slowly that the heat resulting from the chemical change will he conveyed away from the burning surface, by the gases generated, much more rapidly than it is developed; so that the gun-cotton will actually become extinguished when only a small portion of it has been burned.

A very similar result is obtained if gunpowder, either in the form of grains or of one large mass, is exposed to the action of an incandescent platinum wire imbedded in it, the pressure of the atmosphere in the apparatus in which the experiment is made being reduced to between 0·6 and 2 in inches of mercury. The portion of gunpowder contiguous to the heated wire will fuse, vapors of sulphur will be evolved in the first instance, and subsequently the charcoal will be oxidized by the nitre, bubbles of gas escaping from the fused mass. The vapors and gases thus generated convey away rapidly the heat provided by the wire and developed by the chemical action; and at the same time, the change which the gunpowder undergoes diminishes its explosive character, so that its partial ignition or explosion will only be effected after the lapse of several minutes, and if it be in the form of grains, the explosion of the particles contiguous to the wire will have the effect of scattering the remainder without igniting it.

The great reduction in the rapidity of combustion of gun-cotton is not the only result observed when small quantities of that substance are exposed to heat under diminished atmospheric pressure. In the most highly rarefied atmospheres (from 0·5 to 1 inch) the only indication afforded of the burning of the gun-cotton is the appearance of a beautiful green glow, like a phosphorescence, immediately surrounding that part which is undergoing decomposition. When the pressure of the atmosphere is slightly increased, a faint yellow lambent flame appears beyond the green glow, at a short distance from the point of decomposition; and in proportion as the atmosphere is less rarefied, this pale yellow flame increases in volume, while the green phospho-

rescence becomes less and less apparent, until it seems to be completely obliterated. Lastly, when the pressure of the atmosphere is comparatively great (=25 or 26 in inches of mercury) the gun-cotton burns with the ordinary bright flame, though less rapidly of course, than it does under normal conditions of atmospheric pressure. There is no doubt that this bright flame is due to an almost instantaneous secondary combustion (in the oxygen supplied by the air in the apparatus) of the inflammable gases evolved by the decomposition. On the other hand, the production of the small pale flame observed when gun-cotton is burned in more highly rarefied air, or in atmospheres of gases which cannot supply oxygen for combustion, is most probably due to the generation of a mixture of gases (by the change which gun-cotton undergoes under these conditions), which contains not only combustible bodies, such as carbonic oxide, but also a proportion of oxidizing gases (protoxide of nitrogen, or even oxygen); such as a mixture, having self-combustible properties, will receive sufficient heat from the burning gun-cotton to become ignited, except when the atmosphere in which the change takes place is so highly rarefied that the heat is immediately dissipated, and the gases evolved become highly attenuated, as already described.

It will be readily conceived that the mechanical state of the gun-cotton (*i. e.*, the particular form in which it is employed,) like other variable conditions which have been alluded to, will greatly influence the nature of phenomena observed when this substance is ignited in air, or in various gases, either at ordinary or diminished pressures. This may be exemplified by the following experimental illustrations. It has been stated that, when a tuft of carded gun-cotton is ignited in carbonic acid, carbonic oxide, nitrogen, coal gas, hydrogen, and other gases, it burns only with a pale yellow flame; this flame, when furnished by equal quantities of gun-cotton, is much smaller in an atmosphere of hydrogen than it is, for example, in carbonic acid; a fact which must be ascribed to the comparatively very rapid diffusion of the generated gases when hydrogen is used. In operating with pieces of gun-cotton yarn, instead of employing loose tufts, the material when ignited by a red-hot wire in atmospheres of carbonic acid, nitrogen in carbonic oxide, burns much more slowly than it does in air under the same conditions; and its combustion is accompanied only by a very small jet or pointed tongue of pale flame, which is thrown out in a line with the burning extremities of the piece of yarn. In the same way, if the yarn is enclosed in a tube or other vessel through which those gases are circulating, and from which one extremity of the gun-cotton protrudes, when the latter is lighted it will burn in the ordinary manner only until it reaches the opening of the tube, when the form of combustion will at once be changed to that just described. If, however, corresponding experiments are made in atmospheres of hydrogen or coal gas, the gun-cotton yarn will burn in the slow manner described, but only for a brief period—indeed, it ceases to burn at all almost instantaneously, just as it does when ignited in a very highly rarefied atmosphere. This result is not due to the high diffusive powers of the

gas in which the gun-cotton is burned, as it may be obtained equally in open and in perfectly closed vessels; it can, therefore, only be ascribed to the high cooling powers, by convection, of the gases employed. Pure nitrogen, as stated just now, allows the gun-cotton yarn to burn in the slow manner, but if mixed with one-fourth its volume of hydrogen it arrests the combustion of the material, just like coal gas or pure hydrogen.

(To be continued.)

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, January 19th, 1864.

William Sellers, President, in the chair.

Washington Jones, Recording Secretary.

The minutes of the last meeting were read and approved.

The Board of Managers and Standing Committees reported their minutes.

The Board of Managers presented their annual report, which was read, accepted, and ordered to be printed with the minutes.

The Board reported donations to the Library from S. S. Halderman, Penna; Joel Giles, Esq., H. P. M. Berkinbine, Esq., J. J. Barclay, Esq., the Union League, and Prof. John F. Frazer, Philadelphia.

Frederick Arthur Paget, Esq., Civ. Eng. of London, England, was elected a corresponding member of the Institute.

The Special Committees on Weights, Measures, and Coinage of the United States, and on Expansion of Steam, reported progress.

The Report of the Special Committee on a Uniform System of Screw Threads, Bolt Heads and Nuts was considered, when,

On motion, it was ordered that printed copies of the Report be sent to persons and establishments interested in it, and that they be invited to communicate to the Institute their opinions on the subject.

On motion, a Special Committee was appointed to draft a memorial to the City Councils asking that action be taken, under the act passed by the State Legislature in April, 1864, for the appointment of an Inspector of Steam Boilers in the city of Philadelphia; and in making the necessary regulations for the government of the office; the Committee were instructed to report at the next meeting.

Committee Messrs. J. Vaughan Merrick, John H. Towne, John C. Cresson, Fairman Rogers, and Coleman Sellers.

The Tellers for the annual election for Officers, Managers and Auditors, for the ensuing year, reported the result as follows:—

President—William Sellers.

Vice-Presidents.

1. John H. Towne. 2. Fairman Rogers,
3. John F. Frazer.

Secretary—Henry Morton.

Treasurer—Frederick Fraley.

Managers.

B. Henry Bartol,	Henry Cartright,	George Harding,
Pliny E. Chase,	George Erety,	W. Barnet LeVan,
Charles S. Close,	Frederick Graff,	Jacob Naylor,
Charles H. Cramp,	Samuel Hart,	Percival Roberts,
James Dougherty,	William J. Horstmann,	Samuel Sartain,
Washington Jones,	William A. Mitchell,	Coleman Sellers,
J. Vaughan Merrick,	Bloomfield H. Moore,	Samuel S. White,
James S. Whitney,	Henry G. Morris,	O. Howard Wilson.

Auditors.

1. Samuel Mason, 2. James H. Cresson,
3. William Biddle.

Mr. Thomas Shaw exhibited his patent Lubricating Cup for steam engine cylinders, &c. This is so constructed that by a single revolution of a cock the oil will be transferred from the cup to the cylinder without the possibility of any escape of steam from the latter. Mr. S. also exhibited specimens of cylindrical glass tubing for steam gauges, made by Mr. Gillender. The opening in the tubing is broad in one direction and very narrow in the other, so that a small amount of Mercury shall present an extended surface. The specimen exhibited was remarkable for its uniformity in size.

Mr. Shaw also exhibited Mr. Blackwood's Hydraulic Jack, on the outside of the barrel of which is a chamber for the reception of a vertical plunger operated by a lever. This jack may be used either vertically or horizontally.

Mr. J. Field's improved Candle was exhibited. By means of an inverted cone at the lower end of this candle it will readily adapt itself to a candlestick having a socket of any of the usual sizes.

L. Saarboch's improved tobacco pipe was also exhibited.

Mr. J. H. Meissner exhibited his improved Bolt for securing armor plating to the side of vessels, &c. The ends of these bolts are similar to those of the bolt now in use, but a section near the centre of each bolt consists of plaited or twisted strands of wire which this section being welded or otherwise secured to the ends. The screwed point penetrates the wood at the back of the armor and retains the latter firmly in its place, while the elasticity of the wire section prevents the bolt from breaking when the plate is struck by a shot.

Prof. P. H. Vander Weyde submitted for the examination of the members a number of specimens of Photo-lithography.

Prof. Vander Weyde read a paper upon aerial navigation in which the history of the various flying machines was briefly given with some notice of the difficulties which are to be encountered and of the devices which have been suggested for overcoming them.

The Committee exhibited a patent Car or Carriage Spring, invented by Mr. U. B. Vidal.

By his arrangement of the spiral springs, a greater number of spirals can be introduced within a given area, than would otherwise be possible, while all the advantages of the pyromedal spring is secured, namely, greater extent of motion, because the folds of the spring fall

within each other by pressure, instead of upon each other, as with the ordinary form of spiral spring, having thereby greater extent of motion.

By arranging the springs in screws one above the other with plates between each screw, will allow the use of short, stiff springs if desired, without loss of motion, as that may be obtained by additional tiers to make up the difference for the shortening the spring. His object in having slides on the side of the case or box, is to allow the ready examination, and if necessary, the removal of any of the springs, thereby saving time and trouble.

The Committee also exhibited a Gas Carburetter invented by Mr. U. B. Vidal.

Mr. V. proposed by the use of his apparatus to force the gas through coal oil, by which the illuminating power will be increased, the gas becoming saturated with the oil, which at the same time will act as a regulator to the flow of gas.

The case is supplied with oil to about one-third of its capacity, the gas is let on, the pressure of which raises the cup until the holes around its lower edge reaches near the surface of the oil, when the gas passes through the oil, into the outside case to the burner. As the gas is consumed, the cup rises and falls in regular motion, fast or slow, according to the pressure of the gas.

Annual Report of the Board of Managers, for the Year 1864.

In accordance with the By-Laws, the Board of Managers presents its Annual Report of the condition of the affairs of the Institute.

At its stated meeting in March last, upon the recommendation of the Board, the Institute caused an application to be made to the Legislature for such amendments to its Charter as would permit an extension of its scope and powers. This Charter was granted by the Legislature in April of last year, was approved and signed by the Governor on the 25th of the same month, and duly accepted by the Institute in the month following. The Charter thus granted permits the issue of Capital Stock and gives considerable latitude in the details of its organization, so that such alterations may be made from time to time as may appear to be expedient.

At the stated meeting held in June, the new Charter having been accepted, a set of By-Laws was adopted, which, among other changes provides for the transfer to the Board of Managers of the power hitherto exercised by the Institute in conducting its business affairs; the substitution of a resident Secretary, under compensation, to take charge of its library, scientific affairs, and correspondence, instead of the two Secretaries hitherto elected: and the election of all officers except the President, Secretary, and Treasurer, for three years, one-third being elected annually, thus giving a more permanent character to the policy of the Institute.

The present condition of the manufacturing interests of our City, which by their development have advanced her to the front rank of manufacturing localities in the country, renders the establishment of such an Institution as the Franklin Institute on a permanent basis an

imperative necessity. To the well directed efforts of this Institute in past years much of this development is due, but the agencies by which it has worked hitherto, must, in some measure, be replaced by others more suited to the wants of the times, and in some respects, be made more practically useful.

Our library, already valuable in scientific works, and enriched by the collection of British Patents, requires enlargement and classification. More departments should be added to it, each of which, as well as each existing department should be increased by adding such works and periodicals as are required to keep its readers informed in the improvements and discoveries of the day. In this connexion it becomes a subject of interest to determine, whether great advantage might not be derived from such extension of its library as will include standard works not scientific in their character; by thus providing for the literary wants of members, a resort to other libraries would be unnecessary, and our own would become more attractive.

To our lectures on Mechanics and Chemistry, should be added others on subjects connected with their application to the arts.

The building now occupied has become inadequate to our purpose, and if longer used will require alterations so that its rooms may be more comfortable and attractive, as well as more suitable to the purposes for which they are used.

The stated meetings held monthly, might be made far more instructive by the presentation thereat of written papers on subjects connected with the practical arts, and discussions thereon. Steps have already been taken for this purpose; the meeting, being no longer in great measure devoted to the details of conducting the affairs of the Institute, more time is left for scientific discussion; and in December last the first of a series of papers was read on an important subject, that of Photo-lithography. It is believed that persons thus, familiar with the construction of great works in engineering or architecture, and with important processes of the arts, as well as those who may make discoveries in science, will find a suitable place and time for bringing them to public notice, and not only add to the general stock of knowledge, but by a comparison of views enlarge the minds of our members and lead to other discoveries and improvements. The additional interest thus created in the meetings, would render it desirable to hold them in the lecture room, thus avoiding any disturbance to those using the library.

The election of a suitable resident Secretary, whose presence at the Hall will render it always attractive to scientific or practical men, who will intelligently classify its library and see that it is supplied with the most valuable or recent works; who will select from domestic and foreign journals, each month, such valuable hints or descriptions as may be of general interest and who at the stated meeting will share this knowledge with the members, will, it is believed, modify the character of the Institute, making it more useful to its members in their business life, and more a place of resort to them, as the Exchange is to the merchant.

To carry out the improvements already indicated, as well as others which may suggest themselves, requires an expenditure far greater than the Institute, in its present condition, having upon its list many members who have ceased to contribute to its support, since it has ceased to hold exhibitions; and encumbered with a large debt and accumulated interest, the result of an unfortunate effort to advance its position many years ago, is able to carry out. Hence the necessity of enlarging its income, which we believe will be accomplished by the issue of the Stock.

This stock, to the amount of six thousand shares, of a par value of ten dollars each, represents the entire property of the Institute. Its security is good, because that property would bring in the market more than the entire amount of indebtedness. It is of two classes. The First Class, not registered for use, pays no annual fee and may be held to any amount by a single individual. It may, however, be converted into single shares of registered stock, (Second Class) when it becomes liable to an annual tax of three dollars per share. The annual fee for membership having been raised (from necessity) to five dollars, it is not only cheaper to hold a share, but the holder of the share has an ownership in the Institute while he enjoys every privilege of membership. The holder of ten shares not registered for use, enjoys the privileges of membership, and pays no annual fee. He is thus in all respects on a par with life members paying fifty dollars, with the additional advantage of bequeathing this privilege to his survivors or of assigning it to another.

It affords the Board much pleasure to state that by the efforts of individual members, nearly one-half of this stock has been subscribed in sums of 100 shares each by principal manufacturing houses and persons friendly to the arts, in this city; and they believe that a well directed effort on the part of their successors will result in the disposing of nearly all the balance of it in this way; so that a demand will immediately be created for the stock, by persons desirous of registering it for use.

The number of Life Members now on our list is 625, and of annual members in good standing 592, while about half as many more have their names still on the list but have not regularly paid their annual fees. During the past year 57 resignations have been accepted; 3 members have died; and 97 members have been elected; thus adding 37 to the membership. This result in the face of an increase of fees, is gratifying.

But it is hoped and believed that so soon as the efforts now making to re-organize the Institute shall have imparted to it increased vitality, and shall have shown the benefits it can confer, if conducted on an enlarged basis, our list of membership will be very greatly increased. Your Board believes that by its past history, and its past and present objects, the Franklin Institute has a just claim not only on Philadelphians, but on all who are benefited by the progress of the Mechanic Arts and especially on those who live by their exercise.

By the report of the Treasurer it will be seen that the receipts during the past year have been as follows:—

Balance in the Treasury, January 1st, 1864, .	$ 667·81
Receipts during the year, . .	9098·78
	$ 9766·59
And the expenditures have been, . .	9455·68
Leaving a balance in the Treasury of .	$ 310·91

And that the indebtedness of the Institute is as follows:—

	Principal.	Interest accumulated.
5 per cent. Loan,	13,650	4817·50
6 " "	4295	381·26
Mortgages,	7000	210·00
Temporary Loan,	500	110·50
	$ 25,445	$ 5519·26

Total loan and Interest $30,964·26

Annual interest payable on 5 per cent. Loan,	$ 682·50
" 6 " "	257·70
" Mortgages,	420·00
" Temporary Loan,	30·00
Total,	$ 1390·20

It is believed that an earnest effort to induce persons holding certificates of loan, to relinquish them in exchange for the stock of the Institute at par, would result in the sale of a considerable amount of stock and correspondingly reduce the liabilities of the Institute.

The Journal of the Institute, conducted since its foundation and now numbering 78 volumes, is still published monthly, and is a valuable record of the inventions and discoveries of the times. Its publication results in a small pecuniary loss to the Institute, but when its indirect value in the foreign and domestic exchanges is considered, this loss disappears.

During the past year the principal subjects of investigation have been, The adoption of a uniform standard of screw threads, bolt heads, and nuts for general use throughout the United States; and, A comparison of the results practically to be obtained by different measures of expansion of steam, to be determined by experiments now in progress in New York, under the auspices of the Navy Department, and conducted by a joint commission representing the Navy Department, the National Academy, and the Franklin Institute.

In conclusion, your Board would express the conviction that the changes now in progress, when fully consummated, will, with the hearty co-operation of the members of the Institute, be successful in enabling it to become a great instrument for good in the education of all classes in the mechanics and practical arts.

All of which is respectively submitted on behalf of the Board.

JAMES DOUGHERTY, *Chairman.*